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Viruses, Organics, and Other Health-Related Constituents of the Occoquan Watershed and Water-Service Area. Part I: Trihalomethanes, Pesticides and Metals

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This study reports data from a two-year monitoring effort (1975-1977) for several health-related constituents of drinking water in a northern Virginia system (Fairfax County Water Authority) which serves about 640,000 residents. Metals and pesticides were monitored for one year, whereas the trihalomethanes (THM's) were monitored for two. A principal focus of the report is on the temporal variations observed for THM concentrations. Possible causes for these variations are explored in detail. The approach and findings should be useful to scientists and engineers who either are attempting to interpret national studies based on limited sampling from several systems or are planning to design and execute investigations similar to the one described in the report.

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Part I: Trihalomethanes, Pesticides, and Metals

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VIRUSES, ORGANICS, AND OTHER HEALTH-RELATED CONSTITUENTS OF THE OCCOQUAN WATERSHED AND WATER-SERVICE AREA

PART I: TRIHALOMETHANES, PESTICIDES, AND METALS

by

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This report has been reviewed by the Office of Drinking Water, U. S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

The Office of Drinking Water has broad interests in all aspects of rendering a safe drinking water for the American public. These interests run from questions of wastewater and urban impacts on raw water quality to the effects of treatment and the quality of distributed water.

The part of the "Occoquan" project reported herein addresses this broad range of interests with respect to trihalomethanes, pesticides, and metals, in detail and depth, with respect to a single, urbanizing reservoir and water service area. This project should assist engineers and scientists to understand system variations and thereby better interpret results from national studies based on limited sampling from a number of systems. It also supplies indications and directions that should be investigated and considered in planning further studies or details for regulations implementation. It will also provide a "fix" in time for raw and finished water quality for comparison with environmental measurements made in future times as urbanization continues and advanced waste treatment changes are implemented.

PREFACE

The project discussed in this report was begun soon after the passage of the Safe Drinking Water Act in 1974 (P.L. 93-523) and the completion of the EPA's National Organics Reconnaissance Survey (NORS) involving 80 cities in the United States. Late in 1974, the public began to be made aware that drinking water supplies, though microbiologically safe, may be contaminated with hazardous organic chemicals contributed by industries and created during the disinfection process. Extensive coverage by the news media fostered public interest in the subject, and because the data base was so limited at the time, EPA immediately responded by conducting in-house and extra-mural research to determine the extent of the problem and how best to solve it. Since then, much has been accomplished.

This project, referred to as the Occoquan Project, carried out in cooperation with the Fairfax County Water Authority, was conceived initially as an opportunity to study extensively a water system that serves a large population (approximately 640,000) in a rapidly urbanizing area of northern Virginia. The variations in concentrations of heavy metals, pesticides, and selected volatile organics (especially the trihalomethanes) were of special interest, so provisions were made to sample at several intervals during all seasons for two years. The project is truly unique in that, to date, more data concerning both raw- and finished-water concentrations of toxic substances and other water-quality data, exists for FCWA's system than for any other in the United States.

The site for this project was especially attractive because there was an ongoing monitoring program (the Occoquan Watershed Monitoring Program, OWMP) to provide weekly water quality data for the Occoquan Reservoir and its tributaries which could be used in studies of possible correlations between raw- and finished-water quality. Too, during the period of this project an advanced waste treatment (AWT) facility was under construction which would effectively remove pollutants contributed to the reservoir by the discharge of approximately six million gallons per day of secondary treated sewage to Bull Run, one of the major tributaries. The Occoquan Project enabled an expansion of the monitoring effort of the OWMP to include organics, heavy metals, and viruses as part of the preconstruction data base. The AWT plant, owned and operated by the Upper Occoquan Sewage Authority went on-line in late June, 1978, approximately one year after the monitoring provided for by this contract was completed.

The Occoquan Project discussed in this report involved sampling the reservoir, a major tributary, and several sites in the distribution system. In addition to the monitoring for toxic substances, this project provided for extensive virus monitoring and studies relating to virus-monitoring methodology, but the latter will be covered in Part II of this report.

EXECUTIVE SUMMARY

In 1975, a study was initiated in the Occoquan (Virginia) watershed and the water-service area of the Fairfax County Water Authority (FCWA) to monitor both treated and untreated water for a variety of pesticides, toxic heavy metals, and selected volatile organics, particularly those known to be produced by chlorination during water-treatment processes. Of particular interest were 1) the relative magnitudes of pesticide and heavy metal concentrations in treated and untreated waters, 2) the extent of contribution of these hazardous substances from the watershed, 3) the concentration levels of trihalomethanes (THM's) in the finished waters at the water treatment plant and at points distant in the distribution system, and, finally, 4) the concentration variations that might be attributable to seasonal changes or discernible differences in raw- or finished-water characteristics. The project was adjunctive to the Occoquan Watershed Monitoring Program, an ongoing project administered by Virginia Polytechnic Institute and State University under the auspices of the Virginia State Water Control Board. Financing for the monitoring program is supplied by political subdivisions in northern Virginia that lie within the Occoquan Watershed.

The project continued for two years-- from June, 1975 through May, 1977-- but pesticides and heavy metals were monitored only during the first year of the project (Occoquan-I). During Occoquan-I, sampling sites were established 1) on Bull Run, a major tributary to the Occoquan Reservoir, both upstream and downstream of eleven sewage treatment plant discharges; 2) at the raw-water intake of FCWA's water-treatment facilities; 3) at a point in the plant after treatment was complete, and 4) at two sites in the distribution system, one in Alexandria, Virginia and the other in Fairfax County. An open storage reservoir was located between the Alexandria site and FCWA's treatment plant, and this reservoir is filled during the day when the demand is low. In late afternoon and at night, the water from the reservoir is rechlorinated at Cameron Station and used to supplement the flow from FCWA's treatment facilities. During the second year of the study (Occoquan-II), only volatile organics were monitored but a third, distant site in the distribution system (at Dumfries, Virginia) was added.

During Occoquan-I, heavy metals (12 in all) were monitored monthly at all sites, daily during one week in September, 1975, and bihourly on one day (September 11) during that week. Pesticides (10 organochlorine types, 4 organophosphorus-types, and 4 chlorophenoxy herbicides) were monitored with about the same frequency as metals, but more emphasis was given to the organochlorine types. They were monitored weekly for 18 weeks from June into October, 1975. Volatile organics; including the THM's, carbon tetrachloride (CCl_4) and 1, 2-dichloroethane (DCE); were monitored with the same frequency as the organochlorine pesticides. During Occoquan-II,

volatile organics were analyzed monthly at FCWA's raw water intake, at the treatment plant after treatment was complete, and at the three distribution system sites. Twice--during August, 1976 and March, 1977--each site in the distribution system was monitored for THM's on five consecutive days. Two additional features characterized the THM-analysis program during Occoquan-II; 1) duplicate samples were collected and one was dechlorinated to stop the haloform reaction and 2) the total organic carbon (TOC) concentrations were determined.

During both years of the Occoquan project, supplemental studies were conducted periodically to provide additional data concerning factors that affect the haloform reaction. In addition, during both years of the study, supporting data--pH, temperature, chlorine concentrations, etc.--were recorded each time a sample of raw or finished water was collected for analysis.

An additional feature of this project was that an attempt was made to determine, statistically, whether any relationship could be demonstrated between raw water quality and concentrations of THM's in the finished water. A good fit of the data was obtained by multiple regression analyses with several water-quality parameters that reflected the extent of runoff to the reservoir and algae growth within the reservoir. Unfortunately, the equations were not "models," in the sense that they were not predictive, and a much larger data base is required to develop true models. During Occoquan-II, a severe drought occurred, and the water quality at the dam site improved considerably. There was also a commensurate decline in the finished-water THM concentrations, so, while the correlations between water quality and THM's could not be statistically validated because there were insufficient data, one can intuitively suspect that a strong causal relationship exists between THM's, runoff, and algae growth.

The heavy metal concentrations in finished water were routinely low except in three instances: twice involving lead and once involving mercury. These concentrations were not found in subsequent samples and, thus, did not cause a violation of the Primary Drinking Water Maximum Contaminant Level (MCL). Secondary limits (aesthetic limits) for copper, iron, and manganese were exceeded in drinking water collected at the treatment plant but may have reflected corrosion effects from long-standing water in the feeder pipe. No limits were exceeded in other distribution-system samples, indicating minimal aesthetic effects.

Very low quantities of organochlorine pesticides and chlorophenoxy herbicides were detected on numerous occasions in drinking water and, in each instance where an MCL has been established by the Environmental Protection Agency, the concentrations were far below the established limit.

The terminal TTHM concentrations (those attained after reaction to completion under given conditions of available precursors and chlorine) of the individual samples were greater than 100 μg/l 98 percent of the time during Occoquan-I and 85 percent of the time during Occoquan-II. Dechlorinated samples for THM analysis were collected only during Occoquan-II and exceeded 100 μg/l 62 percent of the time. (Trihalomethane regulations proposed by the

Environmental Protection Agency show a limit for TTHM of 100 μg/l based on an annual average in dechlorinated samples). In addition, there were distinct seasonal variations in THM concentrations during both years, but the highest concentrations were observed during different months--in July of 1975 and in October of 1976. Chloroform accounted for approximately 90 percent of the total THM (TTHM) concentrations, and dichlorobromomethane accounted either for all or most of the remaining 10 percent on most occasions. TTHM concentrations during Occoquan-I and Occoquan-II were, respectively: means, 249 and 173 μg/l; medians, 238 and 164 μg/l; and ranges, 40-531 and 43-889 μg/l.

There were distinct seasonal differences not reflected in the statistics just cited, a fact already alluded to, and the variability of the observed THM concentrations was quite high, even when sampling was frequent. The standard deviations, expressed as percents of the means, for the various sampling frequencies during the two-year study were: bihourly, 11 percent; daily, 28 percent; weekly, 30 percent; and monthly, 36 percent. Seasonally, the lowest variations in 1975-1976 were observed during the period of March through May, and in 1976-1977, during December through February.

Trihalomethane concentrations in dechlorinated samples, expressed as a percentage of the terminal concentrations, were lower in the winter than during the summer (45 vs. 72 percent, respectively). There appeared to be a reasonably good linear correlation (R=0.74) between the water temperatures and the $CHCl_3$ concentrations in dechlorinated samples when the concentrations were expressed as a percentage of that in non-dechlorinated samples. The relationship between temperature and the $CHCl_3$ concentrations themselves was poor.

To illustrate the potential variability of annual averages caused by a particular sampling pattern, mean TTHM's (dechlorinated samples),were computed for three combinations of monthly analytical results: 1) January, April, July, and October; 2) February, May, October, and November; and 3) March, June, September, and December. The means so computed varied considerably with a maximum spread of 37 μg/l between the high and low values. This demonstrates the degree of variability which might be experienced in any given system.

Carbon tetrachloride (CCl_4) appeared in 13 percent of the finished water samples collected during Occoquan-II, in concentrations ranging from 1 to 7 μg/l. This compound is not a product of the reaction between chlorine and organic compounds in raw water. The most likely source is from the chlorine gas itself (CCl_4 is a known contaminant of chlorine) because there are no known industrial dischargers of CCl_4 to the Occoquan Reservoir, and none was ever detected in the raw water.

This report was submitted in fulfillment of Contract No. 68-01-3202 by the Research Division of Virginia Polytechnic Institute and State University and its subcontractor, The Carborundum Company, under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from May 23, 1975 through May 31, 1977, and work was completed as of February 1, 1978.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

CCE — Carbon Chloroform Extract
CPH -- Chlorophenoxy herbicides
DCE -- 1,2 - dichloroethane
FCWA — Fairfax County Water Authority
GAC -- granular activated carbon
g/l -- grams per liter
km -- kilometer
MCL -- maximum contaminant level
mg/l — milligrams per liter
MGD — million gallons per day
μg/l -- micrograms per liter
μmol/l -- micromoles per liter
μmhos/cm -- micromhos per centimeter
NOMS — National Organics Monitoring Survey
NORS -- National Organics Reconnaissance Survey
OCP -- organochlorine pesticides
OPI -- organophosphorus pesticides
OWMP -- Occoquan Watershed Monitoring Program
THM -- trihalomethanes
TTHM -- total trihalomethanes
TOC — total organic carbon
UOSA — Upper Occoquan Sewage Authority
VO -- volatile organics
VOA -- volatile organics analysis
VPI & SU — Virginia Polytechnic Institute and State University

SYMBOLS

Ag -silver
As -arsenic
Ba -barium
Cd -cadmium
$CHBrCl_2$ -bromodichloromethane
$CHBr_2Cl$ -chlorodibromomethane
$CHCl_3$ -chloroform
CCl_4 -carbon tetrachloride
Cr -chromium
Cu -copper
Fe -iron
Hg -mercury
Mn -manganese
Pb -lead
Se -selenium
Zn -zinc

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SECTION 1

INTRODUCTION

GENERAL DESCRIPTION OF THE STUDY

In June, 1975, an intensive monitoring effort, hereafter referred to as the Occoquan Project, was begun in the Occoquan, Virginia, watershed and water-service area of the Fairfax County Water Authority (FCWA). The study, which began within six months after EPA's "eighty-city survey" (1) and the enactment of the Safe Drinking Water Act (PL 93-523), was designed to determine the concentration range and variability of a variety of health-related constituents of both the treated water from the FCWA distribution system, which serves approximately 640,000 residents of several northern Virginia communities, and the source water (the Occoquan Reservoir), including one of its major tributaries (Bull Run). The constituents of interest included: a variety of pesticides; haloforms (volatile organics, principally the trihalomethanes); selected heavy metals, many of which are toxic to humans; and certain viruses. The results of the virus monitoring program and other related virus studies are presented in Part II of this report.

The Occoquan Project was conducted by Virginia Polytechnic Institute and State University (VPI&SU) and its subcontractor, The Carborundum Company, as part of a larger, ongoing monitoring effort-- the Occoquan Watershed Monitoring Program (OWMP)-- that is funded by the several political jurisdictions that lie within the watershed and is conducted under the auspices of the Virginia State Water Control Board. That program, begun in 1972, is conducted by VPI&SU and provides weekly data concerning water quality at several points within the Occoquan Reservoir and along its major tributaries. The Occoquan Project provided for an expansion of the water-quality data base compiled by the OWMP before an advanced waste treatment facility, owned and operated by the Upper Occoquan Sewage Authority (UOSA), went on-line in June, 1978. The OWMP, in addition to its routine monitoring, has been the nucleus for several projects involving water-quality assessments, urban runoff, and other related subjects. Reports of several of these studies have appeared in the literature (2, 3, 4, 5).

This report contains a presentation and discussion of data collected during the two-year study of health-related constituents that began in June, 1975. During the first year, chemical water constituents monitored at varying intervals included: six volatile, halogenated organics; ten organochlorine pesticides; three chlorophenoxy herbicides; four organophosphorus insecticides; and twelve heavy metals. (See Table 1). During the second year, only the volatile, halogenated organics were monitored, and a third site in the distribution system (in Dumfries, Virginia) was added. Provisions were made for several, short-term studies with specific, well-defined objectives

TABLE 1. LISTING OF HEALTH-RELATED CONSTITUENTS MONITORED IN THE OCCOQUAN WATERSHED AND WATER SERVICE AREA FROM JUNE, 1975 THROUGH MAY, 1977*

Volatile Organics	Organochlorine Pesticides	Organophosphorus Insecticides	Herbicides	Heavy Metals	Viruses
chloroform	aldrin	azodrin	2,4-D	Ag	enterovirus
bromodichloromethane	chlordane	dimethoate	2,4,5-TP	As	polio
chlorodibromomethane	DDT	ethion	2,4,5-T	Ba	echo
bromoform	dieldrin	vapona		Cd	coxsackie
carbon tetrachloride	endrin			Cr	adenovirus
1,2-dichloroethane	heptachlor			Cu	reovirus
	heptachlor epoxide			Fe	
	lindane			Hg	
	methoxychlor			Mn	
	toxaphene			Pb	
				Se	
				Zn	

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*From June, 1976 through May, 1977 only the volatile organics (with concurrent measurements for total organic carbon) and viruses were monitored.

during both years of the study period. During both years of the study, supplemental water-quality data were collected to aid in characterizing the water when the constituents of major concern were monitored.

BACKGROUND INFORMATION

The Watershed

The watershed (area approximately 580 square miles), whose general location is shown in Figure 1, consists of portions of four counties: Fairfax, Fauquier, Loudoun, and Prince William. Two of the major tributaries join to form the Occoquan Reservoir, which was impounded in 1957. At full pool, the reservoir holds 9.8 billion gallons. The headwaters of the watershed are in forested and agricultural areas. Cedar Run and Broad Run drain areas (approximately 340 square miles) that are almost entirely rural and undeveloped from an urban perspective. On the other hand, Bull Run flows between and adjacent to Fairfax County and the Manassas area, two of the most rapidly urbanizing regions in the United States. Urban runoff and effluents from sewage treatment plants [about 5.4 million gallons per day (MGD)] flow into Bull Run and its tributaries, eventually reaching the reservoir. Construction of an advanced wastewater treatment plant, under the auspices of the Upper Occoquan Sewage Authority (UOSA), was completed during 1978, greatly reducing one source of pollution in the reservoir. Figure 2 shows details of the watershed, including the location of sewage treatment plants and sampling stations that are routinely monitored as part of the Occoquan Watershed Monitoring Program. The urbanized areas, constituting approximately twenty percent of the total watershed, are mainly along Bull Run (bordering Manassas), along Flat Branch (draining Manassas to Bull Run), and along Big Rocky Run (a tributary to Cub Run).

The Sampling Sites

During the first year of the study, there were six sampling sites: two on Bull Run upstream and downstream of major discharges of treated sewage and urban runoff, two at the FCWA's Lorton Water Treatment Facility (both raw and finished waters) located near the reservoir high dam, and two at distant points in the distribution system. During the second year, a third site in the distribution system was added, and most of the sampling that year did not include the sites on Bull Run. A more detailed description of the sampling sites is given in Table 2.

The particular location for Site F was selected originally because an open-storage reservoir is located between it and the water treatment plant. During the day, when the demand is low, the reservoir fills. Between 4:00 p.m. and midnight, when the demand is high, the reservoir is used to supplement the flow from the FCWA plant. However, during this study, most all samples were taken at times when there was no contribution from the open reservoir.

Figure 3 shows the locations of Sites A-E, which were within the watershed. Sites F and G lay outside the watershed, E being approximately 14 miles (22.5 km) southeast of the center of Fairfax and 12.5 miles (20.2 km)

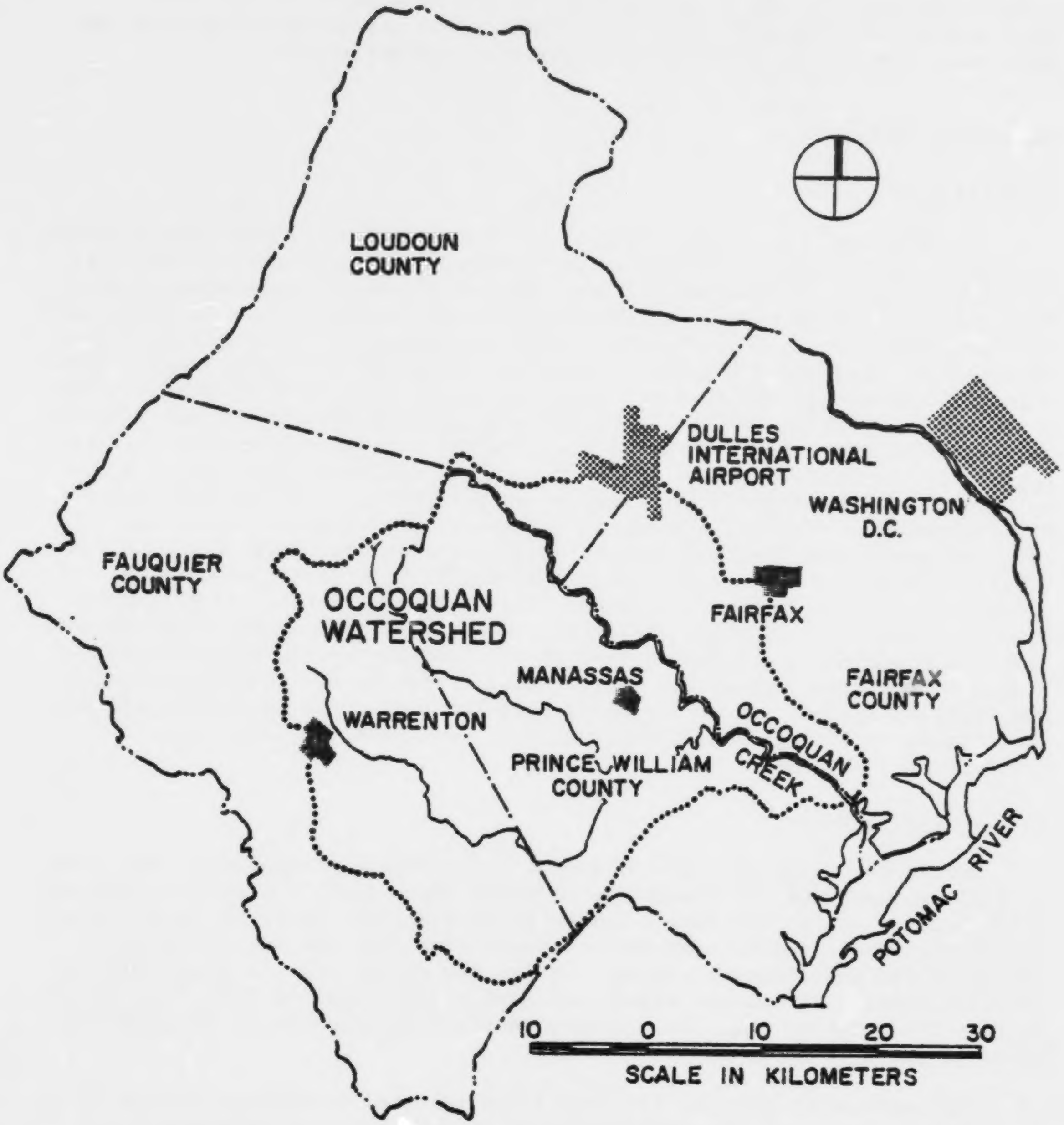
LOUDOUN COUNTY
DULLES INTERNATIONAL AIRPORT
WASHINGTON D.C.
FAUQUIER COUNTY
OCCOQUAN WATERSHED
FAIRFAX
MANASSAS
FAIRFAX COUNTY
WARRENTON
OCCOQUAN CREEK
PRINCE WILLIAM COUNTY
POTOMAC RIVER
10
0
10
20
30
SCALE IN KILOMETERS

Figure 1. Map showing general location of the Occoquan Watershed in relation to Washington, D.C.

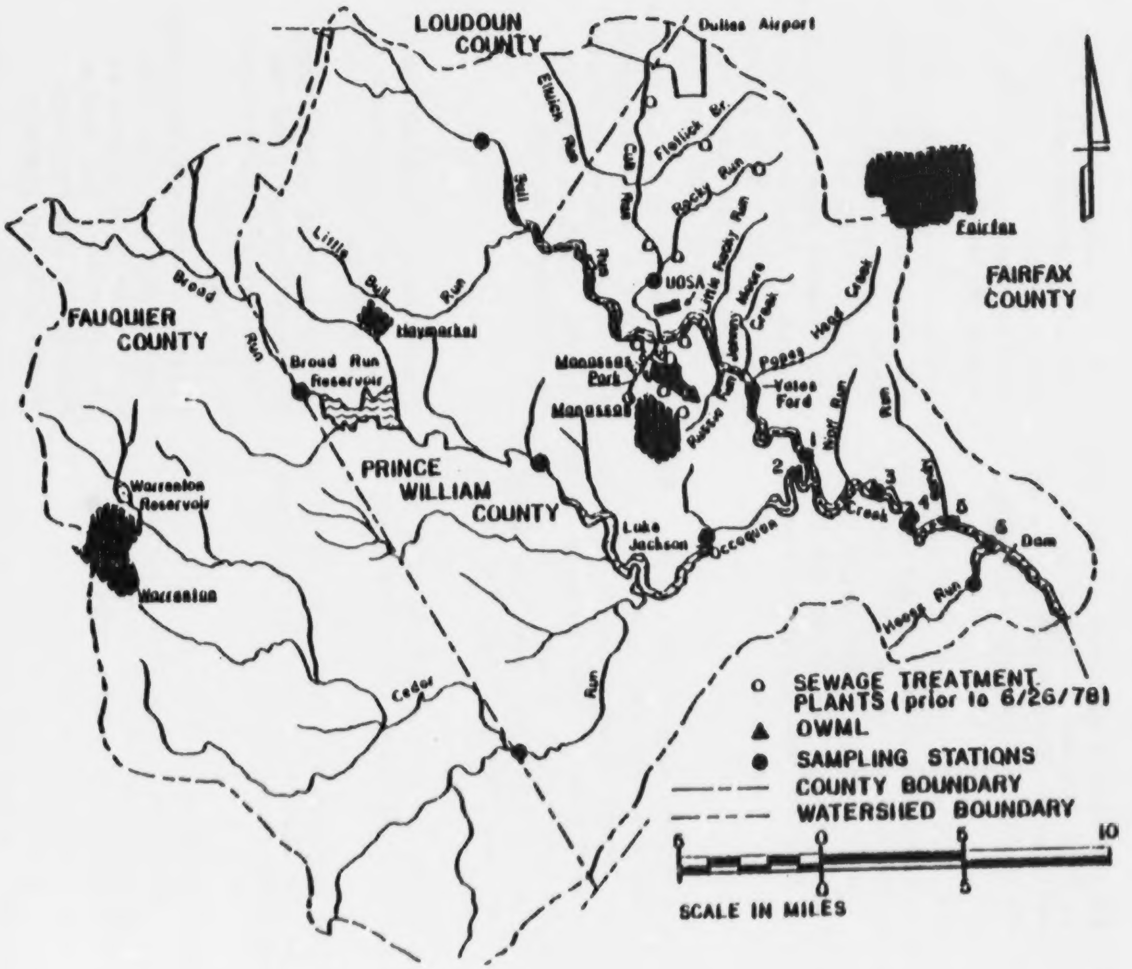
LOUDOUN COUNTY
Dulles Airport
FAIRFAX COUNTY
Fairfax
FAUQUIER COUNTY
PRINCE WILLIAM COUNTY
Elklick Run
Cub Run
Flatlick Br.
Rocky Run
Little Rocky Run
Johnny Moore Creek
Popes Head Creek
Bull Run
Little Bull Run
Broad Run
Broad Run Reservoir
Haymarket
UOSA
Manassas Park
Manassas
Russia Run
Yates Ford
Wolf Run
Occoquan Creek
Lake Jackson
Hooes Run
Dam
Cedar Run
Warrenton Reservoir
Warrenton
1
2
3
4
5
6
SEWAGE TREATMENT PLANTS (prior to 6/26/78)
OWML
SAMPLING STATIONS
COUNTY BOUNDARY
WATERSHED BOUNDARY
5
0
5
10
SCALE IN MILES

Figure 2. The Occoquan Watershed showing locations of 1) the Occoquan Watershed Monitoring Laboratory (OWML), 2) Sampling Stations of the Occoquan Watershed Monitoring Program, 3) former sites of municipal waste treatment plants, and 4) the Upper Occoquan Sewage Authority's (UOSA) advanced waste treatment plant.

TABLE 2. OCCOQUAN PROJECT SAMPLING SITE LOCATIONS AND DESCRIPTIONS*

Site	Location	Conditions
A	On Bull Run, 23 miles upstream of the confluence of Bull Run and Occoquan Creek. Site is designated "Catharpin" and is at a point where Rt. 705 crosses Bull Run.	Forested and agricultural areas. Represents conditions upstream of major sewage treatment plants and urban drainage.
B	On Bull Run, 3.1 miles below confluence with Cub Run and 2.3 miles below the discharge of the last of 11 sewage treatment plants. The site is 14 miles below Site A, approximately 9 miles above the confluence of Bull Run and Occoquan Creek.	Average flow approximately 75 cfs. Bull Run at this point has received approximately 5.4 MGD of treated, chlorinated sewage from 11 plants (6 from Prince William Co. and 5 from Fairfax Co.) as well as urban and agricultural drainage.
C	Approximately 1000 feet below the Occoquan Reservoir dam from the raw water main to the Fairfax County Water Authority's (FCWA) water treatment plant. Samples were taken from inside the "carbon house". The site is approximately 18 miles from Site B and 9 miles from confluence of Bull Run and Occoquan Creek.	Raw water as received by the Fairfax Co. Water Authority's (FCWA) three treatment plants, combined capacity approximately 60 MGD.
D	Pump Station No. 2 of the Lorton High Service Plant at FCWA water treatment plant.	A mixture of finished waters from the three treatment plants of the FCWA.
**E	Within the distribution system in Fairfax County at the Fairfax County Storage Yard on Hwy 29 near County Road 645.	Finished water approximately 10 hours distant from the FCWA water treatment plants at average flow.
F	The Prince Street Fire Station in Alexandria, Va. At times, water from an open storage reservoir is rechlorinated and used to supplement flow from FCWA.	Finished water approximately 8 hours distant from FCWA water treatment plants at average flow. The system belongs to the Virginia American Water Company.
G	The Dumfries-Triangle Volunteer Fire Department, Inc. 18329 Jefferson Davis Highway.	Finished water approximately 13 hours distant from FCWA water treatment plants at average flow. The water going to this site is derived totally from the Occoquan Treatment Plant.

*Site A is sampled routinely as part of the OWMP. The other sites listed are separate from those sampled by OWMP personnel.

**This site was sold in February, 1978, and is no longer under FCWA's control.

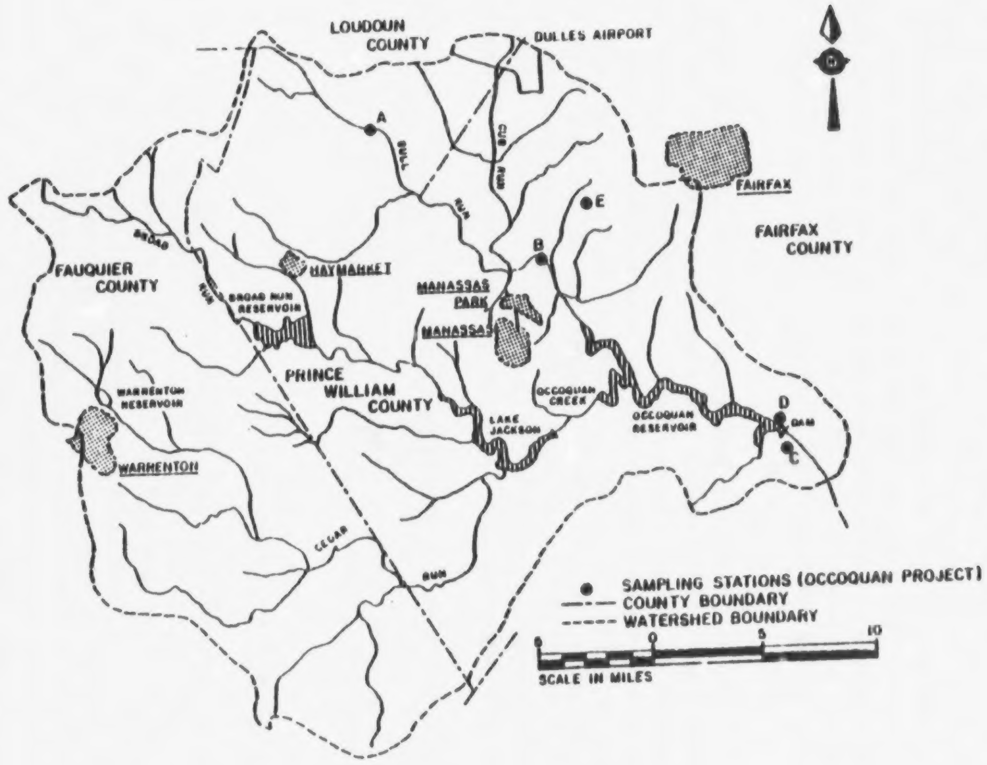
LOUDOUN COUNTY
DULLES AIRPORT
A
BULL
RUN
CUB RUN
E
B
FAIRFAX
FAIRFAX COUNTY
BROAD
RUN
FAUQUIER COUNTY
HAYMARKET
BROAD RUN RESERVOIR
MANASSAS PARK
MANASSAS
C
PRINCE WILLIAM COUNTY
WARRENTON RESERVOIR
WARRENTON
LAKE JACKSON
OCCOQUAN CREEK
OCCOQUAN RESERVOIR
D
DAM
C
CEDAR
RUN
SAMPLING STATIONS (OCCOQUAN PROJECT)
COUNTY BOUNDARY
WATERSHED BOUNDARY
0
5
10
SCALE IN MILES

Figure 3. The Occoquan Watershed, showing five of the seven sites sampled during the Occoquan Program, 1975-1977. The network of sampling sites monitored weekly by the ongoing Occoquan Watershed Monitoring Program is shown in Figure 2.

northeast of the dam site. Site G was approximately 17 miles (27.3 km) south of Fairfax and 7 miles (11.3 km) south-southwest of the dam site.

Description of FCWA's Water Treatment Facilities

Fairfax County Water Authority has three interconnected treatment plants: the Occoquan Plant, the Old Lorton Plant, and the New Lorton Plant. The latter was dedicated in 1973, and it employs conventional sedimentation and filtration. The other two plants utilize Aldridge sedimentation-filtration units. The design capacities of the three plants, in million gallons per day (MGD), are 20, 26.4, and 16, respectively, although the operating rates allowed by the Virginia State Health Department have been increased to permit production rates of 111.6 MGD with increased monitoring of turbidity in the finished water. The Occoquan Plant employs tube sedimentation and high-rate filtration at rates of 4-5 gallons per minute per square foot (gpm/ft^2). The other two plants employ conventional filtration at rates of 2 gpm/ft^2 and higher.

Water is taken from the Occoquan Reservoir through a 72-inch main. Pretreatment is usually chlorination only, but provisions are made for the addition of powdered activated carbon. Alum is the principal coagulant, but ferric salts are used occasionally. After flocculation, settling, and filtration, additional chlorine is added, and lime is added to increase the pH to approximately 7.5. Backwash water is sent to a reclamation basin, and from there the settled water is recycled to the head of the New Lorton plant. Subsequent to the field sampling period covered by this project, the chlorination points in all three plants was moved in 1977-1978 to the settling basin discharge.

During the project period, the average finished-water production rate varied from 56.5 to 75.1 MGD (See Table 3). The approximate contribution by each of the three plants, as a percentage of the total during 1975-1976, were as follows: Occoquan, 45 percent; Old Lorton, 25 percent; and New Lorton, 30 percent.

Characteristics of Raw and Finished Water

Table 4 shows the average raw and finished-water charactersitics recorded at the New Lorton facility during the project period. The data are shown as average quarterly values and include most of the routinely monitored constituents. Periodically, comprehensive analyses of the waters are performed, and concentrations of selected heavy metals, total organic carbon (TOC), carbon chloroform extract (CCE), chlorides, sulfates, phosphorus, nitrates, and total solids are determined. In summer, 1977, a monitoring program for trihalomethanes (THM's) was begun by FCWA personnel to evaluate the effectiveness of varying treatment processes in reducing finished-water THM concentrations.

As can be seen from Table 4, the raw water is low in alkalinity (and dissolved solids, as reflected by the low specific conductivity), and addition of coagulants reduces the pH to less than 7.0, necessitating lime addition to increase the buffering capacity of the finished water. Powdered activated carbon is added periodically to control tastes and odors generated primarily by algae in the reservoir. Copper sulfate is applied at several

TABLE 3. AVERAGES AND RANGES OF FINISHED WATER PRODUCTION RATES AT FAIRFAX COUNTY WATER AUTHORITY DURING PROJECT PERIOD

Time Period		Finished Water Production Rate, MGD[a]	
		Average	Range
June-Sept.	1975	65.9	52.5 - 89.5
Oct.-Dec.	1975	56.5	51.6 - 63.2
Jan.-March	1976	57.7	53.0 - 63.5
April-June	1976	72.5	60.0 - 99.0
July-Sept.	1976	75.1	60.7 - 97.0
Oct.-Dec.	1976	63.7	56.7 - 74.2
Jan.-March	1977	63.6	56.2 - 74.3
April-May	1977	72.4	61.3 - 98.4

[a] MGD=million gallons per day. To convert to cubic meters per day, multiply values shown by 0.264.

TABLE 4. AVERAGE CHARACTERISTICS OF RAW AND FINISHED WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S NEW LORTON TREATMENT FACILITY DURING PROJECT PERIOD, MAY 1975-MAY 1977

Time Period		Turbidity Units		Alkalinity, mg/l		pH Units		Color Units		Hardness, mg/l		Mn^{++}, mg/l		Specific Conductance, μmhos/cm		Total Chlorine, mg/l
		Raw	Fin.	Raw	Fin.	Raw	Fin.	Raw	Fin.	Raw	Fin.	Raw	Fin.	Raw	Fin.	Fin.
May-June	1975	2.7	0.10	35	40	7.2	7.7	27	3	46	67	0.10	0	-	-	1.9
July-Sept.	1975	8.2	0.12	34	41	6.8	7.3	58	5	42	72	0.19	0.01	96	151	2.6
Oct.-Dec.	1975	8.7	0.12	30	36	6.9	7.5	53	3	42	70	0.09	0	112	160	2.7
Jan.-March	1976	19.1	0.20	25	28	7.1	7.6	55	5	43	64	0.07	0	104	147	2.4
April-June	1976	5.7	0.10	30	37	6.9	7.5	50	3	45	71	0.13	0	104	162	2.9
July-Sept.	1976	1.9	0.07	44	50	7.0	7.5	25	5	52	75	0.17	0	134	192	3.3
Oct.-Dec.	1976	18.2	0.15	27	32	7.0	7.5	79	5	42	72	0.17	0	84	122	2.9
Jan.-March	1977	8.4	0.27	33	37	7.0	7.6	49	11	53	91	0.14	0.01	121	174	2.5
April-May[a]	1977	5.8	0.05	29	31	7.0	7.4	45	10	44	75	0.10	0	-	-	2.6

[a] Data through May 19, 1977.

points in the reservoir, usually from May through October. In 1975, 78.7 tons were applied, 69 percent of which was in July and August. In 1976, only 52.7 tons were applied, approximately 52 percent being added in July and August. Since 1971, the Authority has successfully improved raw water quality at the intake by forcing air through perforated, plastic pipes that lay on the bottom of the reservoir extending from the dam for several hundred feet upstream.

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SECTION 2

CONCLUSIONS

The significant conclusions derived from an analysis of data collected during this study are:

1. Monthly, grab-sample concentrations of toxic metals for which Primary Drinking Water Maximum Contaminant Levels (MCL) exist were routinely low in Fairfax County Water Authority's (FCWA) drinking water except in three instances, twice involving lead and once involving mercury. These instances in themselves did not cause a violation of the regulations because such concentrations were not detected in subsequent samples.

2. Maximum secondary levels (aesthetic limits) for copper, iron and manganese were exceeded in FCWA's drinking water collected at their New Lorton treatment facility, possibly reflecting the corrosion effects of long-standing water in the feeder pipe. No limits were exceeded elsewhere in the distribution system, indicating minimal aesthetic effects.

3. Very low concentrations of organochlorine pesticides and chlorophenoxy herbicides were detected on numerous occasions in the FCWA's finished water but never were the concentrations high enough to exceed an MCL in those instances where one has been established by the Environmental Protection Agency.

4. Dechlorinated samples for total trihalomethanes (TTHM) analysis were collected only during Occoquan-II and exceeded 100 ug/l 62 percent of the time. (Trihalomethane regulations proposed by the Environmental Protection Agency show a limit for TTHM of 100 ug/l based on an annual average in dechlorinated samples.)

5. TTHM concentrations in unquenched samples (i.e., those not dechlorinated at the time of collection) exceeded 100 ug/l in FCWA finished water 98 percent of the time during 1975-76 and 85 percent of the time during 1976-77. Chloroform routinely accounted for approximately 90 percent of the TTHM concentration.

6. The variations in THM concentrations were quite high, even when sampling was frequent. However, the variability (expressed by the standard deviation as a percent of the mean) decreased with increased sample frequency. During the two years, these variations were: bihourly (one day only), 11 percent; daily (for three weeks), 28 percent; weekly (for eighteen weeks), 30 percent; monthly (for nineteen months), 36 percent.

7. There are distinct seasonal variations in the THM concentrations in FCWA finished water, the highest appearing in the early summer of 1975 but shifting to the early fall of 1976. The lowest variations in 1975-1976 were observed during the period from March through May (15 percent), and in 1976-1977, during December through February (21 percent).

8. Instantaneous trihalomethane concentrations, expressed as percents of the terminal concentrations at the consumer's tap, were lower in the winter than in the summer (45 vs. 72 percent, respectively). There appeared to be a reasonably good linear correlation between water temperature and dechlorinated sample $CHCl_3$ concentrations expressed as a percentage of the terminal concentrations.

9. The variability of the TTHM concentrations markedly affected the magnitude of several "annual averages" computed for three combinations of monthly analytical results for 1976-77: 1) January, April, July and October; 2) February, May, October and November; and 3) March, June, September, and December. The means for these three groups of data varied considerably (105-142 ug/l in dechlorinated samples) with a maximum spread of 37 ug/l between the high and low values. This demonstrates the degree of variability which might be experienced in any given system.

10. Detailed review of the relative THM data for the distribution samples, as compared to each other and to the treatment plant samples, indicates the following:

    a. The THM concentrations in non-dechlorinated samples from the treatment plant were about the same as those at the distribution points during both 1975-76 and 1976-77. This would seem to indicate that THM's in a single, non-dechlorinated sample collected at the treatment plant could be considered as representative of the entire distribution system.

    b. During 1976-77, the THM concentrations in the dechlorinated samples at the treatment plant and the two relatively close distribution points were equivalent, but those at the far-distant distribution site (Site G) were significantly higher than at the treatment plant.

c. A special study, twice repeated at Site G in June, 1977, showed that initial samples had no detectable free-chlorine residuals and very low THM concentrations but that subsequent samples collected one and five minutes after the tap was opened had both substantial levels of free chlorine and THMs. This indicates that some process may be operating to lessen THM concentrations in a distribution system, and this possibilty merits further investigation.

d. Plots of data from analyses of weekly, daily and hourly non-dechlorinated samples from the treatment plant and two distribution points for four months in 1975 were roughly comparable except at Site F in the evening and during the night of September 11, 1975 (starting at 1600 hours). During this period, the THM concentrations at Site F were significantly lower, a fact explainable by pumpage from a supplemental storage reservoir (beginning at 1600 hours) which would provide a water with a much shorter exposure to chlorine and, consequently, lower concentrations of THMs. These data emphasize the need for precise observations of distribution conditions to facilitate interpretation and understanding of water quality variations.

11. Finished-water trihalomethane concentrations correlated well with the variables that related to raw water chlorine demand and to those related to runoff, e.g., rainfall and reservoir elevation. Good fits of the data could be obtained by the multiple regression analyses, but none of the regression equations was a true model because none was predictive. There was no consistent correlation between finished water THM concentrations and total organic carbon concentrations in either the untreated or finished water.

12. Reservoir algal densities (expressed as chlorophyll a) were not included in the statistical analyses, but the available evidence shows that the summertime algal chlorophyll a concentrations in the Occoquan reservoir vary approximately linearly with finished-water THM concentrations, strongly suggesting that algae contribute significantly to the pool of THM precursor organic compounds in that body of water.

13. Carbon tetrachloride (CCl_4) appeared in 13 percent of finished water samples, during 1976-1977 in concentrations ranging from 1 to 7 ug/l. The most likely source is the chlorine used at the water treatment plant. No CCl_4 was detected in raw water during this period. During 1975-1976 CCl_4 and 1,2-dichloroethane were not separately identified.

SECTION 3

RECOMMENDATIONS

Five areas of additional study in connection with trihalomethanes are recommended:

1. Additional efforts should be made to determine the relative importance of humates and algal metabolites as THM precursors in the Occoquan Reservoir. If the algae prove to be significant contributors, as all the available data indicate that they are, then increased attention to algal growths near the raw water intake should be carefully monitored, especially during the period from May through October, and appropriate control measures instituted at the first indication of increased growth.

2. Additional studies should be conducted to determine whether the FCWA distribution system may provide reactants or may by some other means cause a reduction in THM concentrations when free chlorine is no longer present. More attention should be given to distribution system conditions, such as the presence of slimes or trapped air, which could promote either an increase or a decrease in THM concentrations or reduce the free chlorine residual to zero.

3. Some additional research should be conducted to determine if some raw-water quality parameter could be used as an indicator of the need for special treatment to minimize THM's.

4. Efforts should be made to determine the source(s) of CCl_4 and DCE that were measured in several finished-water samples. If these are contaminants of the chlorine gas used by FCWA, steps should be taken to minimize them.

5. Consideration should be given to analyses of water for total organic halogens (TOX) in order to obtain a more complete evaluation of chlorine by-product concentrations than one has when only THM's are monitored.

SECTION 4

MATERIALS AND METHODS

HEAVY METALS

Samples for heavy metals were collected in acid-washed, glass jars (approximately two liters) and preserved with nitric acid. Sufficient acid was added to decrease the pH to 2.0 or less. The jars were then covered with a thin, polyethylene film and sealed with a lid used for sealing jars typically used for the home-canning of foods.

Analyses were conducted by atomic absorption spectroscopy with a Perkin-Elmer Model 403 Atomic Absorption Spectrophotometer equipped with a deuterium background corrector. Most metals were analyzed by direct aspiration of the sample into the flame. However, when concentrations of some metals, principally lead, approached the detection limit, the samples were extracted with methylisobutyl ketone (MIBK), according to procedures described by Mulford (1), and the extracts were aspirated into the flame.

Arsenic and selenium were analyzed by the gaseous hydride method (2) and mercury by a flameless procedure (3). These latter procedures permit detection at concentrations much lower than is possible by methods used for other metals.

Standards were prepared daily by dilution of commerically available stock solutions (Fisher Scientific Company) with a glass-distilled water that had been passed through an anion-cation exchanger after distillation. At the request of EPA, the laboratory at VPI&SU participated in a quality-assurance program to verify the precision of the analytical procedures, and the results were deemed satisfactory. The laboratory routinely participates in a similar program by the United States Geological Survey.

PESTICIDES

Samples for pesticide analyses were collected in amber glass jugs that held approximately four liters. They were transported to VPI&SU, usually within no more than two weeks after collection, and were stored at approximately 4°C until they could be analyzed. No special precautions were taken to preserve the samples because the pesticides of interest are slowly biodegradable.

The analyses were conducted according to procedures described in Appendix A of the National Pollutant Discharge Elimination System discussion presented in the Federal Register (4). The procedures entailed extraction of the samples with solvents (methylene chloride in hexane for the organophosphorus and organochlorine pesticides, and diethyl ether for the chlorinated phenoxy acids and their esters) and subsequent analysis by gas chromatography (GC). Standards were obtained from the Environmental Protection Agency in Cincinnati, Ohio, and the laboratory at VPI&SU that was responsible for the analyses.

At the beginning of the study, EPA's Quality Assurance Branch submitted pesticide samples (unknowns) to the analysts' laboratory (Department of Biochemistry Pesticide and Organics Analysis Laboratory) to verify their ability to detect the pesticides in question. The results were satisfactory. Routinely, as is accepted practice, the analysts spiked one water sample with pesticides being analyzed and carried these samples through the entire analytical scheme. This procedure was repeated each day analyses were performed. The hexane extracts were passed through dry Florisil columns (6 g.) for clean-up, and two fractions of the filtrate (the first and second 50-75 ml portions) were analyzed for the pesticides. Typical recoveries were greater than 90 percent in all instances.

During the analyses of both raw water and finished drinking water, many unidentified peaks consistently appeared on the chromatograms. These were noted but were not identified because such work was not required by the contract. However, in several instances, pesticides required by the contract which were identified in the samples by GC procedures were verified by mass spectroscopy at VPI&SU.

VOLATILE ORGANICS

Sample collection procedures were the same during the two-year program, but more attention was given to standardizing the sample-handling procedures in the second year's effort. Details are given in the following sections.

Sample-Collection Procedures

Samples for volatile organics analyses (VOA) were collected in 50-ml, glass bottles previously cleaned with detergent, distilled water, and acetone, then heated at 550°C to combust any residual acetone and organic matter not removed by the washing procedure. The sample bottles were filled to overflowing, and a teflon disk was carefully positioned to avoid entrapment of air in the bottle. Then, an aluminum cap was placed over the teflon liner and firmly secured by crimping its edges with a commercially available crimping tool. The samples then were placed on wet ice and shipped by air express to Sacramento, California, for analysis at the California Analytical Laboratories. During the second year, duplicate, finished-water samples were collected and one was dechlorinated by adding sufficient potassium ferrocyanide to reduce 10 mg/l chlorine.

Sample Handling and Analysis Procedures

Sample Handling--

During the first year of the study, there were no specific instruction given to the analysts regarding sample-handling procedures that should be followed prior to the actual analyses because at that time not much was known about the environmental variations that could affect the concentrations of volatile organics in sample containers during storage. However, information became available during the first year of study that showed storage conditions and the time lapse before analysis possibly could affect the results, so in the second year, detailed sample-handling procedures were specified as part of the VOA protocol the analysts should observe. During the first year, steps were taken to ensure that samples were not contaminated by haloforms in the atmosphere. These steps included 1) removing all volatile organics from the refrigerator used to store samples prior to their analysis and 2) sealing of each sample in its own polyethylene bag. Later, it became known that the time lapse between collection and analysis was important, so in the second year of study, it was specified that samples should be analyzed no sooner than seven days nor later than fifteen days after collection.

That year, the samples were placed on ice at the time of collection and were shipped (usually the next day) to the analytical laboratory by air express. The time in transit usually was one day, but never longer than two days. Prior to analysis, the samples were left standing at ambient room temperature (ca.22°-23°C) for a period not less than seven days and, as was specified in the contract, the total elapsed time between sample collection and analysis never exceeded fifteen days.

Sample Analysis--

All VOA's were by the Bellar-Lichtenberg procedure (5), a purge/trap procedure wherein volatile organics are sparged with an inert gas (nitrogen or helium) and adsorbed on a resin inside a "trap." The trap is then heated rapidly and the desorbed VO gases are swept into the GC column. The detector is a coulometric detector that is particularly sensitive to halogenated organics but not other types of "contaminating" organics.

During the study, personnel at the California Analytical Laboratories and The Carborundum Company collaborated closely with Bellar and Lichtenberg at EPA in Cincinnati to keep abreast of rapidly developing improvements. At the beginning of the project, the analysts participated in a quality assurance program with EPA in Cincinnati and proved themselves quite capable of obtaining reliable data at the μg/l level. Additional quality assurance tests have been conducted by the California Department of Health, and there is an established "internal" quality control program wherein at least one sample in each set is spiked with several of the THM's. Typical recoveries have been in the 90 to 100 percent range. The internal quality control program was approved by both EPA and the California Department of Health.

Occasionally, though it was not specified in the contract to do so, the volatile organics analyzed by gas chromatography were confirmed by mass spectroscopy. These confirmations were particularly useful in the first year of the study to ensure the reliability of the analytical procedures for identifying the specific volatile organics of concern and to eliminate the possibility that other compounds with similar retention characteristics as the volatile organics might be producing artifacts.

During the first year of the study, and through most of the second, the particular GC column packing employed in the VOA procedure did not permit separation of 1,2-dichloroethane (DCE) and carbon tetrachloride (CCl_4). In February, 1977, a change was made in the type of packing, and for the remainder of the study, DCE and CCl_4 were effectively separated during the analyses.

SUPPLEMENTAL WATER QUALITY DATA

Supplemental water quality data required by the contract included chlorine residuals (free and total), pH, temperature, bacterial counts (coliforms and total plate counts, the latter on finished water only), and notes concerning any unusual characteristics such as high turbidity and any unusual color or odor. All methods were according to Standard Methods For the Examination of Water and Wastewater (6). During the second year, monitoring of finished waters for total organic carbon (TOC) was required.

Chlorine Residuals

Both total and free residuals were determined by the DPD Ferrous Titrimetric Method Sec. 409 E. The reliability to 0.1 mg/l was verified by testing aliquots of samples by the Amperometric Titration Method, Sec. 409 C. The titrimetric method was suitable for analysis of all but the most turbid samples, as are common to the tributary streams of the reservoir after a rainstorm, but the residuals there were less than 0.1 mg/l on all occasions. The principal sites where chlorine residuals were important were those where finished water samples were collected.

pH Value

The pH of all samples was determined according to Standard Methods Section 424. A portable pH meter was used and standardized before each use with commercially available buffer solutions.

Temperature

Temperature was measured according to Standard Methods Section 212 with a mercury-filled Celsius thermometer calibrated in increments of 0.1 C. The thermometer was placed in the sample immediately after collection and allowed to equilibrate before the reading was taken.

Bacterial Counts

Coliforms--

The Multiple-Tube Fermentation Technique (Section 908) was used for both total coliforms (908 A) and fecal coliforms (908 C). Both the presumptive and confirmed tests were performed using five transplants of aliquots from the serial dilutions. Occasionally, the completed test was performed to verify the identification reliability. Both raw and finished-water samples were analyzed for coliforms, and the dilutions and media inoculations were performed in the field. The tubes were returned to the laboratory for incubation within four to six hours.

Total Plant Counts--

The standard plate count procedure (Section 907) was performed only on finished waters. Plates were inoculated in the field at the time samples were collected and returned to the laboratory for incubation within four to six hours.

Total Organic Carbon (TOC)--

The TOC concentrations were determined (during Year 2) by analysis with a Beckman Instruments 915A TOC Analyzer. Potassium phthalate standards were used so that full-scale deflection on the strip chart recorder was 20 mg/l, and the reproductivity of analyses of standards was within 0.2 mg/l of the true concentration. During the latter part of the study period, the laboratory acquired a Dohrmann/Envirotech Model 54 TOC Analyzer, permitting analyses with precision to less than 50 µg/l TOC.

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SECTION 5

RESULTS AND DISCUSSION

HEAVY METALS

Of the 12 heavy metals that were monitored, only four-- Cu, Fe, Mn, and Zn-- were present consistently at all six sampling sites. The average concentrations of these metals and their variations; observed in samples collected monthly, daily, and bihourly; are shown, respectively, in Tables 5, 6, and 7. Appendix A contains the individual data from which these tables (and others to be presented later) were constructed.

Concentrations in Raw Water

The soils in the Occoquan Reservoir contain an abundance of Fe and Mn, a fact reflected by the high concentrations in Bull Run at Sites A and B. At the dam (Site C), concentrations of both these metals were considerably higher than in Bull Run because the hypolimnetic waters in the reservoir either are anaerobic or contain little oxygen (<10 percent saturation) during May through September causing the Fe and Mn to exist in the reduced state, which makes both metals more soluble than when they are oxidized. The FCWA aerates the hypolimnion by forced-air injection through perforated tubing that extends several hundred feet upstream from the dam. However, even this treatment does not prevent the anaerobic sediments from releasing Fe(II) and Mn(II).

Both Cu and Zn appeared in relatively low concentrations in water from Bull Run at Sites A and B even though Bull Run receives urban runoff that normally contributes considerable quantities of Zn. Apparently, dilution and removal by adsorption onto sediment are preventing water concentrations from becoming high. Table 6 shows that Zn concentrations in raw water at the dam site were lower than in Bull Run, most likely because Zn is removed by adsorption onto suspended solids that settle in the reservoir; however, Cu concentrations increased. The FCWA applies massive quantities of copper sulfate ($CuSO_4$) during May through October for algae control at several points in the reservoir, including near the dam site, so it was not surprising that Cu concentrations at Site C were greater than in Bull Run.

None of the other heavy metals (Ag, As, Ba, Cd, Cr, Hg, Pb, and Se) ever appeared in significant concentrations in water at Sites A or B. At Site C (the dam site), Ag, As, Cd, Cr, Hg, and Se seldom were observed; while Ba and Pb appeared frequently in low concentrations.

Finished Water Concentrations

As might be expected, both Fe and Mn concentrations were reduced by FCWA water treatment processes, though the average Fe concentration exceeded

TABLE 5. STATISTICAL EVALUATION* OF MONTHLY VARIATIONS OBSERVED IN TRACE METALS CONSISTENTLY PRESENT AT SITES IN THE OCCOQUAN WATERSHED AND WATER SERVICE AREA, JUNE,1975-MAY,1976

Site	METAL, μg/1											
	Copper			Iron			Manganese			Zinc		
	$\bar{x}$	s	range	$\bar{x}$	s	range	$\bar{x}$	s	range	$\bar{x}$	s	range
A	14	9.3	(0-35)	460	182.2	(264-850)	53	56.2	(11-195)	34	55.4	(6-207)
B	32	68.5	(4-248)	517	193.1	(270-980)	103	28.1	(50-148)	46	93.1	(6-339)
C	169	130.2	(9-417)	1185	962.5	(272-3720)	434	466.2	(94-1560)	31	40.9	(4-158)
D	329	356.4	(40-1404)	579	493.8	(50-1390)	23	18.0	(3-57)	173	178.3	(25-628)
E	399	333.8	(36-1089)	41	26.2	(0-80)	7	6.0	(0-15)	73	54.0	(12-192)
F	55	37.2	(30-161)	96	61.6	(30-260)	10	7.4	(0-23)	57	57.2	(10-217)

Site A: Upstream of Occoquan Reservoir on Bull Run above treated sewage discharges.
Site B: Upstream of Occoquan Reservoir on Bull Run below treated sewage discharges.
Site C: Intake, FCWA Water Treatment Plant.
Site D: Finished Water, FCWA Water Treatment Plant.
Site E: Distribution System: FCWA Storage Yard.
Site F: Distribution System: Alexandria, Virginia.

* $\bar{x}$ = Mean Value: rounded to nearest whole number. Average concentration during week of Sept. 9-15 was considered as September mean with bihourly mean on Sept. 11 used as the Sept. 11 mean for Sites C, D, E, and F. October values were averaged for Sites E and F.

s = Standard deviation.

TABLE 6. STATISTICAL EVALUATION* OF DAILY VARIATIONS OBSERVED IN TRACE METALS CONSISTENTLY PRESENT AT SITES IN THE OCCOQUAN WATERSHED AND WATER SERVICE AREA, SEPTEMBER 9 - 15, 1975

Site	METAL, µg/1											
	Copper			Iron			Manganese			Zinc		
	$\bar{x}$	s	range	$\bar{x}$	s	range	$\bar{x}$	s	range	$\bar{x}$	s	range
A	17	11.7	(0-33)	264	22.3	(240-300)	30	6.2	(22-39)	8	3.0	(5-11)
B	21	9.5	(12-38)	413	63.7	(380-550)	88	20.9	(54-119)	20	20.4	(7-65)
C	302	166.4	(172-581)	1486	1182.2	(380-3310)	1560	1392.0	(215-3610)	28	21.8	(6-59)
D	255	99.1	(80-395)	633	381.4	(108-1390)	5	7.7	(0-21)	164	96.4	(32-314)
E	357	234.2	(35-647)	32	14.7	(15-60)	Found once, 8 µg/1			25	26.7	(4-83)
F	71	48.0	(44-179)	61	32.4	(30-130)	Found once, 2 µg/1 (bihourly)			32	15.4	(6-54)

Site A: Upstream of Occoquan Reservoir on Bull Run above treated sewage discharges.
Site B: Upstream of Occoquan Reservoir on Bull Run below treated sewage discharges.
Site C: Intake, FCWA Water Treatment Plant.
Site D: Finished Water, FCWA Water Treatment Plant.
Site E: Distribution System: FCWA Storage Yard.
Site F: Distribution System: Alexandria, Virginia.

* $\bar{x}$ = Mean Value: rounded to nearest whole number. September 11 values = average of bihourly analyses.

s = Standard deviation.

TABLE 7. STATISTICAL EVALUATION* OF BIHOURLY VARIATIONS OBSERVED IN TRACE METALS CONSISTENTLY PRESENT IN UNTREATED AND FINISHED WATER, SEPTEMBER 11, 1975

	METAL, μg/1											
Site	Copper			Iron			Manganese			Zinc		
	$\bar{x}$	s	range	$\bar{x}$	s	range	$\bar{x}$	s	range	$\bar{x}$	s	range
C	188	86.4	(111-346)	646	188.4	(350-960)	608	262.5	(192-909)	6	3.8	(0-12)
D	80	47.7	(22-214)	108	82.8	(30-370)	1	2.4	(0-6)	32	28.6	(4-116)
E	35	7.8	(25-48)	15	14.8	(0-40)	0	-	-	4	4.1	(0-11)
F	44	9.0	(30-61)	58	25.1	(10-100)	Found once, 2 μg/1			6	5.5	(0-17)

Site C: Intake, FCWA Water Treatment Plant.
Site D: Finished Water, FCWA Water Treatment Plant.
Site E: Distribution System: FCWA Storage Yard.
Site F: Distribution System: Alexandria, Virginia.

* $\bar{x}$ = Mean Value: rounded to nearest whole number.

s = Standard deviation.

the water quality standard of 0.3 mg/l at Site D. Apparently, iron precipitated in the distribution system enroute to Sites E and F, because, as is shown in Table 5, the average concentrations at these locations were nearly an order of magnitude less than at the treatment plant. On the other hand, concentrations of Cu and Zn were higher in finished water at all sites, caused, no doubt, by contributions from the piping. It should be mentioned that Fe, Mn, Cu, and Zn included in the proposed national standards are secondary standards because those elements do not adversely affect human health. Those proposed standards (Fe, 0.3 mg/l; Mn, 0.05 mg/l; Cu, 1.0 mg/l; and Zn, 5.0 mg/l) are intended to ensure that both the aesthetic and organoleptic quality of the water supply are acceptable (1). At the time this study was performed, the approval limits in force were those of the Virginia State Health Department's Bureau of Sanitary Engineering, and these elements were labeled "aesthetics." A statistical summary of the data for observed Cu, Fe, Mn, and Zn concentrations is presented in Table 8. As can be seen, the proposed national standards were seldom exceeded except that for Fe, which was exceeded 14 percent of the time, most frequently at Site D.

Table 9 contains a synopsis of the finished water data concerning trace metals for which MCL's in finished water are specified (2). Note that the MCL for Pb was exceeded twice, both times at Site D when the observed concentrations were 100 and 80 µg/l. The mercury MCL was exceeded once, but since it and lead were not found in subsequent samples, the proposed MCL's were not considered to have been violated. It should be mentioned that lead was never detected at Site A, only once at Site B, but eight times at Site C (mean, 31.4 µg/l). The increase most likely can be explained by the fact that the reservoir is located in a highly urbanized area and receives considerable metal pollution from urban runoff and in rainfall (3,4). On the dates when lead exceeded standards at Site D, the concentrations were zero in the raw water. However, lead was detected approximately 30 percent of the time (Table 9) in finished water. A Community Water Supply Study conducted in 1969 (5) revealed that 1.4 percent of 969 water supplies contained lead in excess of the MCL of 0.05 mg/l. It was mentioned that under certain conditions, lead concentrations can become considerably high when water stands overnight in lead pipes. Therefore, it is possible that lead is being contributed by the piping at the treatment plants, but according to a recent report of the National Research Council (NRC) of the National Academy of Science (NAS) (6), lead can also be contributed during the treatment of water, presumably as contaminants in the treatment chemicals as well as from the hardware within the system itself. The report cited a study in which metals concentrations in both raw and finished waters from 1577 systems were compared. Higher mean concentrations of Fe, Zn, Pb, Cu and Al in finished waters were evident from the five-year study conducted in the 1960's.

PESTICIDES

Organochlorine Pesticides (OCP)

All the OCP's are insecticides that can be grouped for discussion in four categories. While an exhaustive review of the chemical and toxicological information regarding these compounds is beyond the scope of this report, a brief review of some pertinent facts will be helpful in interpretation of the data obtained during the Occoquan study. For more detail, the interested

TABLE 8. FINISHED WATER (SITES D, E, AND F) CONCENTRATIONS OF TRACE METALS FOR WHICH SECONDARY STANDARDS ARE PROPOSED

Element	Standard, µg/1	Samples Positive		Times Exceeding Standard	Concentrations When Detected		
		No.	Percent		Mean	Range	Standard Deviation
Cu	1000	92	100	2	168	(21-1404)	235
Fe	300	86	93	12	176	(10-1390)	303
Mn	50	37	40	2	14	(2-57)	12
Zn	5000	84	91	0	66	(2-628)	97

TABLE 9. FINISHED WATER (SITES D, E, AND F) CONCENTRATIONS OF TRACE METALS FOR WHICH THERE ARE PRIMARY STANDARDS, JUNE, 1975 THROUGH MAY, 1976

Element	*Proposed Standard μg/l	Total Analyses	Times Detected	Times Exceeding Standard	Concentrations When Detected, μg/l		
					Mean	Range	Standard Deviation
Ag	50	92	1	0	-	0-1	-
As	50	92	0	0	-	-	-
Ba	1000	92	32	0	47	10-200	41.5
Cd	10	92	6	0	2	1-4	1.1
Cr	50	92	3	0	11	3-20	8.5
Hg	2	92	2	1	-	0-2.5	-
Pb	50	92	32	2	21	1-100	20.8
Se	10	92	0	0	-	-	-

*Became effective June, 1977.

reader is referred to the National Academy of Sciences (NAS) 1977 report entitled "Drinking Water and Health" (6) from which the following facts regarding the OCP's were obtained. Most concern regarding the environmental impact of the OCP's centers about the facts that many of them are known or suspected carcinogens, are extremely resistant to chemical or biological decomposition, and tend to concentrate in organisms at successively higher trophic levels in food chains.

Classes of OCP's--

The ten OCP's monitored in raw and finished water during the Occoquan study fall into four distinctly different classes of organic compounds. These are discussed briefly.

Cyclodienes-- Six of the ten OCP's were in this group, all derivatives of hexachlorocyclopentadiene. Included are: aldrin and dieldrin, which are highly persistent and carcinogenic and which were banned October 1, 1974; endrin; chlordane and heptachlor, which were suspended for use on agricultural crops on April 1, 1976; and heptachlor epoxide. This group is regarded by the NAS to be the most hazardous of all the residual pesticides in water. The only one for which a MCL has been established is endrin (MCL: 0.2 ppb), and that standards is based on chronic toxicity effects. An approval limit of 0.5 ppb was in force during the period covered by this study.

Chlorinated Ethanes-- Included are DDT, which was banned for all but essential public health uses on January 1, 1973, and methoxychlor. DDT is ubiquitous in the environment because it is highly persistent and bioconcentrates. DDE is the principal breakdown product. The toxicity of DDT is related to chronic effects, though there is also a definite carcinogenic risk. There is no interim drinking water standard for DDT. The interim standard for methoxychlor is 0.10 mg/l. It is not bioconcentrated and has a low mammalian toxicity. During the project period, there were limits in force of 0.05 mg/l DDT and 0.10 mg/l, both specified in the Virginia Water Works Regulations.

Hexachlorocyclohexanes-- Lindane is the gamma isomer (one of eight) of "benzene hexachloride" (BHC). (Commerical grade lindane is 99% pure gamma isomer). An interim standard of 4 ppb has been established by EPA.

Camphene derivatives-- Toxaphene is a complex mixture of at least 175 compounds, only 10 of which have been identified structurally. It is the least understood of all the OCP's but apparently has not caused a great deal of environmental harm. Residues are seldom detected on raw agricultural products and, hence, toxaphene is not likely to appear in finished drinking water.

Observed Concentrations of OCP's in the Occoquan Study--

Tables 10 and 11 present summaries of the observed occurrences of OCP's, respectively, in raw and finished waters during the Occoquan study. As can be seen from Table 10, three OCP's-- DDT, dieldrin, and heptachlor epoxide-- were detected in raw water at one or more of the three locations at least 34 percent of the time. The para-para (p-p') isomer of DDT is shown because

TABLE 10. SUMMARY OF ORGANOCHLORINE PESTICIDE OCCURRENCES IN UNTREATED WATERS AT THREE SITES, JUNE, 1975 - MAY, 1976

ORGANOCHLORINE PESTICIDE	TOTAL OBSERVATIONS	NUMBER POSITIVE*	STATISTICAL ANALYSIS OF CONCENTRATIONS WHEN FOUND,* VALUES IN MICROGRAMS PER LITER		
			Mean	Standard Deviation	Range
Aldrin	108	10	0.006	0.005	0.002-0.015
Chlordane	108	2	0.379	Observed Twice	0.370&0.387
pp-DDT	108	44	0.342	0.668	0.001-3.000
Dieldrin	108	34	0.152	0.687	0.001-4.000
Endrin	108	7	0.081	0.150	0.000-0.400
Heptachlor	108	3	0.001	0	-
Heptachlor Epoxide	108	39	0.006	0.007	0.001-0.028
Lindane	108	24	0.047	0.103	0.001-0.395
Methoxychlor	108	15	0.368	0.681	0.008-2.000
Toxaphene	108	2	0.369	Observed Twice	0.237&0.500

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* Greater than trace quantities, varying from 0.001 to 0.010 micrograms per liter, depending on the particular pesticide being analyzed.

TABLE 11. SUMMARY OF ORGANOCHLORINE PESTICIDES OCCURRENCES IN FINISHED WATER, JUNE, 1975 - MAY, 1976

ORGANOCHLORINE PESTICIDE	TOTAL OBSERVATIONS	NUMBER POSITIVE*	STATISTICAL ANALYSIS OF CONCENTRATIONS WHEN FOUND VALUES IN MICROGRAMS PER LITER		
			Mean	Standard Deviation	Range
Aldrin	132	4	0.015	0.013	0.004-0.030
Chlordane	132	1	Observed once at 41 nanograms per liter, Site E		
pp-DDT	132	27	0.050	0.066	0.001-0.230
Dieldrin	132	1	Observed once at 2 nanograms per liter, Site E		
Endrin	132	0	-	-	-
Heptachlor	132	3	0.002	0.002	0.001-0.004
Heptachlor Epoxide	132	13	0.018	0.026	0.009-0.100
Lindane	132	5	0.006	0.003	0.004-0.009
Methoxychlor	132	21	0.066	0.104	0.001-0.500
Toxaphene	132	0	-	-	-

* Greater than trace quantities, varying from 0.001 to 0.010 micrograms/liter, depending on the pesticide being analyzed.

it accounted for from 80 to 90 percent of the technical product used for years. Its presence, in spite of the limited ban since 1973, attests to its persistence in the environment. The high detection frequencies of dieldrin and heptachlor epoxide and correspondingly low detection frequencies of aldrin and heptachlor can be explained by the fact that dieldrin and heptachlor epoxide are the major degradation products that persist after application, respectively, of aldrin and heptachlor. Lindane was observed to be present in more than 25 percent of the raw water samples.

The concentrations of the various OCP's in finished waters (Sites D, E, and F), shown in Table 11, illustrate the persistence of DDT and heptachlor epoxide through the treatment system. However, none of the existing standards was ever exceeded. Methoxychlor appeared with approximately the same frequency in finished water as in raw water (16 vs. 14 percent of the time). Generally, but not always, the OCP's were observed most often at Site D. The mean concentrations for DDT, heptachlor epoxide, methoxychlor concentrations were, respectively, 39, 8.8, and 82.7 nanograms per liter. Endrin was never observed in finished water and never was an established MCL for any OCP exceeded. Appendix B, Tables B-1 through B-6, contains the results of the individual analyses for OCP's throughout the sampling period. Note that those in eight of the samples were confirmed by mass spectroscopy.

Table 12 shows the concentrations of the OCP's recovered from selected sites within FCWA's Lorton treatment facility and from the effluents of three experimental granular activated carbon (GAC) filters that had been in operation for approximately three months. While none of the MCL's were exceeded, it is interesting to note that the concentrations of methoxychlor in the GAC filter effluents were relatively high when compared to those in water at various locations in the plant. Except for that in the effluent from the 2 ft. WestVaCo WV-G Column (Site Z4), the concentrations of methoxychlor from the carbon columns approximated the mean concentration observed in finished waters during the entire study period (Table 11). The WestVaCo carbon's capacity for most of the pesticides appeared to have been exceeded at the time of this particular sampling and, in fact, seemed to be desorbing certain ones of the accumulated pesticides. The intent of the brief study was to determine the pesticide removal effectiveness of various water treatment processes, but the data are too few to substantiate any definite conclusions. A comparison with data in Appendix Table B-7 (bihourly analyses on September 11, Site C) shows that OCP concentrations appeared to be reduced through the treatment plant, but because there was no way to follow a slug of water through the plant, no definite statement can be made concerning the sequential removal by the various water treatment processes.

The OCP's were also monitored bihourly on September 11, 1975, at Sites D, E, and F (finished waters). The results of the individual analyses appear in Appendix B, Tables B-8 through B-10. Dieldrin, DDT, and heptachlor epoxide appeared in a majority of the raw-water samples; while methoxychlor and aldrin, though present, appeared less frequently. During this sampling period, only DDT and methoxychlor appeared in measurable concentrations at Site D. Samples from Site E were relatively free of any OCP, and none from Site F showed measurable concentrations of any OCP.

TABLE 12. CONCENTRATIONS OF ORGANOCHLORINE PESTICIDES OBSERVED IN SPOT SAMPLES TAKEN AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT PLANT, SEPTEMBER 11, 1975 (No Data Indicates None Found)

Time	Site[+]	PESTICIDE, μg/l									
		Aldrin[a]	Chlordane[b]	DDT*[c]	Dieldrin[a]	Endrin[c]	Heptachlor[a]	H. Epoxide[a]	Lindane[a]	Methoxychlor[c]	Toxaphene[d]
2400	M	-	-	T	-	-	T	T	-	-	-
2050	N	T	-	0.01	-	-	T	T	-	-	-
2115	P	-	-	0.024	-	-	-	T	-	-	-
2215	S	T	-	T	T	-	-	-	T	0.04	-
2250	X2	-	-	T	T	-	T	T	T	0.03	-
2310	Y3	T	-	T	-	-	-	T	T	0.02	-
2325	Z4	0.006	T	0.01	T	0.008	T	T	0.008	0.25	-

[*] pp isomer

[a] T = <0.001 μg/l

[b] T = <0.005 μg/l

[c] T = <0.002 μg/l

[d] T = <0.01 μg/l

[+] Sites M & N before flocculator
Site P before clarifier
Site S filter applied
Site X_2, Effluent from experimental GAC bed (Filtrasorb-400, 1 ft)
Site Y_3, Effluent from experimental GAC bed (Filtrasorb-400, 2 ft)
Site Z_4, Effluent from experimental GAC bed (WestVaCo WV-G, 2 ft)

Organophosphorus Insecticides (OPI)

There are no interim primary standards (2) for any of the OPI's, but four representatives of this class of pesticides were included in the first year of the Occoquan monitoring study because the OPI's, as a class, are widely used in the United States. Even though their effects on humans can be quite severe (they inhibit proper nerve impulse transmission by inhibition of cholinesterase), the OPI's are not as persistent in the environment as the chlorinated pesticides and generally are not regarded as serious hazards in water because they rapidly break down. (The interested reader is referred to an EPA publication: "The Fate of Select Pesticides in the Aquatic Environment," Reference 7).

During 1975, a total of 48 raw-water samples and 34 finished-water samples (Table 13) were analyzed for four OPI's: dimethoate, azodrin (common name: monocrotophos), vapona (common names: DDVP and dichlorvous), and ethion. Only once was any OPI detected (dimethoate, 0.068 μg/l, at Site A on August 26, 1975). There was concern that the prescribed analytical procedure, involving a flame ionization detector, was not sensitive enough, so all analyses were replicated using the ^{63}Ni electron detector. Still no OPI's were detected.

Chlorophenoxy Herbicides (CPH)

The herbicides are of importance in assessing water quality because they are widely used to control aquatic and terrestrial weeds, and there is a possibility that they may enter potable source waters. Two herbicides are used extensively in the United States: 2,4-D (2,4-dichlorophenoxyacetic acid) and 2,4,5-TP (Silvex) [2-(2,4,5-trichlorophenoxy) propionic acid]. A third, 2,4,5-T (2,4,5-trichlorophenoxyacetic acid), has been banned for major use as an aquatic weed control chemical (2). The contract which provided for the Occoquan study did not require that 2,4,5-T be analyzed, but because it would appear during the gas chromatographic analysis for the other two, its presence, if detected, was routinely reported. At the time of sampling, the Virginia Water Works Regulations specified approval limits of 0.02 mg/l for 2,4-D and 0.03 mg/l for 2,4,5-TP. The interim primary drinking water regulations (2) presently specify approval limits of 0.1 mg/l and 0.01 mg/l for 2,4-D and 2,4,5-TP, respectively, values that are 20 percent of the assumed safe levels of these compounds in the total diet of animals. These safe levels were derived from laboratory-determined dosages required to induce toxic effects (both chronic and acute) in rodents and dogs.

Table 14 shows a statistical summary of the analytical results of the CPH analyses. Even though the herbicides were detected in a majority of both raw and finished water samples, the concentrations never even closely approached the MCL's. (Individual data are in Appendix B, Tables B-11 through B-14). It is interesting that 2,4,5-T, even though banned, did appear in low concentrations four times in raw water samples and twice in finished water.

TABLE 13. ORGANOPHOSPHORUS INSECTICIDE ANALYSIS FREQUENCY DURING JUNE - NOVEMBER, 1975

Sampling Date		Sites					
		A	B	C	D	E	F
June	2			X	X		
	3					X	X
	4	X	X				
	9			X	X		
	10	X	X				
	11					X	X
	16			X	X		
	17	X	X				
	18					X	X
	23			X	X	X	X
	24	X	X				
	30			X	X	X	X
July	1	X	X				
	7			X	X		
	8	X	X				
	14			X	X	X	X
	15	X	X				
	21			X	X	X	X
	28			X	X	X	X
	29	X	X				
August	5	X					
	11			X	X	X	
	12	X	X				
	18			X		X	
	25			X	X		
	26	X	X				
September	9	X	X	X	X		
	11						
	12	X					
	15	X		X			
	22			X	X		
	23	X	X				
October	6			X	X		
	7	X	X				
November	10			X	X		
	11	X	X				

TABLE 14. SUMMARY OF HERBICIDE OCCURRENCES IN UNTREATED WATER AT THREE SITES (A, B AND C) AND IN FINISHED WATER AT THE FCWA WATER TREATMENT FACILITY (SITE D), JUNE, 1975 - MAY, 1976

HERBICIDE	OCCURRENCES/ OBSERVATIONS [+]		STATISTICAL ANALYSIS OF CONCENTRATIONS WHEN FOUND[+]					
			Mean		Standard Deviation		Range	
	Raw	Finished	Raw	Finished	Raw	Finished	Raw	Finished
2, 4-D	18/33	6/11	0.297	0.226	0.468	0.196	0.006-2.000	0.006-0.400
2, 4, 5-TP	25/33	9/11	0.031	0.129	0.049	0.270	0.001-0.200	0.001-0.800
[*]2, 4, 5-T	4/33	2/11	0.012	0.008	0.005	-	0.005-0.018	0.007&0.008

[+] Values in micrograms per liter.

[*] Not required by contract.

Possible Relationships Between Pesticides Concentrations and Land Uses in the Occoquan Watershed

It has been mentioned previously that no data are available that might be used to predict the precise sources of pesticides found in the reservoir and its tributaries, though it is probably true that runoff from both urban and agricultural areas contribute the vast majority of the pesticides detected. It should be emphasized that no samples were taken from the Occoquan Creek tributary of the reservoir, and it is the one that drains the largest land mass within the watershed. Table 15 was prepared to compare the land uses in the two sub-basins of the Occoquan Watershed. The heaviest pesticide applications, no doubt, would be in the tilled areas, which totalled 67.3 and 24.7 square miles, respectively, for the Occoquan Creek and Bull Run Watersheds.

Examination of the individual pesticide concentration values in Appendix B shows that pesticide concentrations generally increased downstream from Site A to Site B in Bull Run. However, concentrations at the dam (Site C) were often much higher, indicating that there were inputs from sources other than Bull Run. For example, the mean concentrations and standard deviations for DDT at Sites B and C were, respectively, 0.17 ± 0.5 μg/l (16 samples) and 0.57 ± 1.0 μg/l (11 samples). Most of the urban runoff entering the Occoquan Reservoir has entered Bull Run upstream of Site B, and other than from some slight agricultural activity along the northeast boundary of the reservoir, there are no sources except Occoquan Creek for sizeable pollutant loads to enter. These facts, considered along with data presented in Table 15 concerning land use, lead one to suspect that Occoquan Creek is a significant contributor of the total pesticide load entering the Occoquan Reservoir. There should be no real cause for concern regarding the safety of the water supply, however, because no pesticide standard was exceeded during the study period.

VOLATILE ORGANICS

Volatile organics were monitored routinely for two years during the Occoquan study, and, in addition, a number of short-term experiments were conducted to contribute information regarding factors that influence haloform production in water supplies. The routine monitoring effort during 1975 and 1976 (hereafter referred to as Occoquan-I) differed in several respects when compared to the second year's study during 1976 and 1977 (hereafter referred to as Occoquan-II).

The differences were as follows:

1. During Occoquan-I, the sampling frequency was greater during the summer and fall.
2. Duplicate samples were collected during Occoquan-II, one of which was dechlorinated immediately to stop the haloform reaction; the other was allowed to stand a minimum of seven days at room temperature prior to analysis. During Occoquan-I, only one sample was collected and it was not dechlorinated. Too, all samples were kept at 0-5°C until they were analyzed.
3. Precise procedures for sample handling and storage prior to analysis were specified during Occoquan-II to ensure that all

TABLE 15. A COMPARISON OF LAND USES IN THE TWO SUB-BASINS OF THE OCCOQUAN WATERSHED

Land Use	TOTAL BASIN		BULL RUN SUB-BASIN		OCCOQUAN CREEK SUB-BASIN	
	mi^2	%	mi^2	%*	mi^2	%*
Urban						
"Estate" Residential	1.54	0.26	0.80	0.14	0.00	0.00
Large Lot Single Family	14.57	2.50	6.89	1.18	7.47	1.28
Medium Density Single Family	9.98	1.71	8.07	1.38	0.52	0.09
Townhouse Garden Apartments	2.08	0.36	1.67	0.29	0.29	0.05
Commercial	2.59	0.44	1.27	0.22	1.28	0.22
Industrial	5.60	0.96	3.64	0.62	1.88	0.32
Institutional	3.46	0.59	1.23	0.21	2.19	0.38
TOTAL	39.82		23.55		13.63	
Agricultural						
Pasture	116.94	20.03	19.92	3.41	97.00	16.61
Conventional Tillage Grain	29.64	5.08	12.16	2.09	17.21	2.95
Mixed Conventional Tillage/Livestock	47.87	8.20	9.98	1.71	37.57	6.43
Minimum Tillage Grain	5.46	0.94	1.60	0.27	3.86	0.66
Mixed Minimum Tillage/Livestock	12.35	2.12	3.74	0.64	8.61	1.47
Sodfarm/Golf Course	2.21	0.38	1.73	0.30	0.48	0.08
TOTAL	214.47		49.13		164.73	
Forest and Idle Land	329.60	56.45	118.02	20.21	180.45	30.90
GRAND TOTAL	583.89		190.70		358.81	

* % of total basin area

NOTE: Land use information obtained from Northern Virginia Planning District Commission.

samples were treated uniformly. During Occoquan-I, samples were stored in ice immediately after collection and during shipment and then in a refrigerator at 0°-5°C before analysis.

4. During Occoquan-II, sampling from the Bull Run sites was discontinued and a third site in the distribution system was added.

These differences, coupled with the fact that the climatological conditions were quite different during the two years, have made it desirable to present and discuss the data collected during phases I and II separately before they are considered together.

It should be mentioned that since this project began in 1975, much research data has been published on a variety of topics related to the reduction and control of volatile organics, particularly the trihalomethanes (THM), in public water supplies. On February 9, 1978, the EPA published proposed amendments (8) to their previously published Interim Primary Drinking Water Regulations (2) that dealt specifically with the control of organic contaminants in drinking water. A MCL of 100 µg/l total THM (TTHM) was proposed, that value being the average of the concentrations of the THM's detected in samples of finished water which are dechlorinated at the time of collection. In this section of the report, part of the data analysis will be discussed in relation to that proposed MCL and, in addition, some discussion will be given to a consideration of factors the authors believe influenced the THM concentrations in FCWA's finished water. Of course, it was recognized, even as this report was being written, that research is continuing and new data may either substantiate or refute some of the interpretations of the data presented herein.

Occoquan-I: 1975-1976

Frequency and Distribution--

Table 16 shows the frequencies that volatile organics were detected in samples of raw and finished waters during the first year of the program. Both $CHCl_3$ and $CHBrCl_2$ were present in all finished-water samples; and $CHCl_3$, though present in lower concentrations, was detected in the majority of the raw water samples. Table 17 compares the concentrations of $CHCl_3$ (the THM always present in highest concentrations) in raw and finished water. These data demonstrate what both Rook (9) and Bellar et al. (10) showed earlier, namely that chlorination of natural waters is responsible for THM formation. Note from Table 17 that the addition of several million gallons of treated, chlorinated sewage to Bull Run (dilution approximately tenfold) did not appreciably increase the $CHCl_3$ concentrations above those measured in samples from a station above the treatment works. Chloramines, the only chlorine forms in effluents containing ammonia, are generally the only chlorine species present in sewage effluents, and they do not react with organic precursors to form THM's (11).

Figure 4 shows that the THM concentrations observed in finished water during the entire Occoquan Study (phases I and II) were most likely normally distributed. (The data-fit on log-normal probability paper did not approximate a straight line). The distribution pattern is an important consideration

TABLE 16. FREQUENCY OF VOLATILE ORGANICS GREATER THAN OR EQUAL TO ONE MICROGRAM PER LITER AT ALL SAMPLING SITES, June, 1975 - May, 1976

SITE	TOTAL OBSERVATIONS	$CHCl_3$		$CHBrCl_2$		$CHBr_2Cl$		DCE + CCl_4*		$CHBr_3$	
		No.	%	No.	%	No.	%	No.	%	No.	%
A	26	18	69	0	0	0	0	4	15	0	0
B	27	21	78	2	7	0	0	5	18	0	0
C	42	25	60	2	5	0	0	3	7	0	0
D	43	43	100	43	100	4	9	1	2	0	0
E	45	45	100	45	100	2	4	0	0	0	0
F	43	43	100	43	100	10	23	0	0	1	2

Site A: Catharpin on Bull Run above major sewage treatment plant discharges
Site B: Bull Run below major sewage treatment plant discharges
Site C: Intake, Fairfax County Water Authority's water treatment facility (FCWA)
Site D: Finished water; FCWA Water Treatment facility
Site E: Distribution System, FCWA's storage yard
Site F: Distribution System, Alexandria, Virginia

* Dichloroethane + Carbon tetrachloride, separation not attained

TABLE 17. CHLOROFORM CONCENTRATIONS (MICROGRAMS PER LITER), VARIABILITY, AND FREQUENCY IN WATERS FROM ABOVE AND BELOW SEWAGE TREATMENT PLANT DISCHARGES AND IN RAW AND TREATED DRINKING WATER FROM JUNE, 1975 THROUGH MAY, 1976

Site	Chloroform Concentration, µg/l			Percent Positive
	Mean	Standard Deviation	Range	
A: Upstream Control: at Catharpin on Bull Run	2.2	2.8	0-11	68
B: On Bull Run 2.3 Miles Below the last of 11 Chlorinated Sewage Treatment Plant Discharges	3.2	4.3	0-20	78
C: Water Treatment Plant Intake	3.0	5.2	0-26	62
D: Water Treatment Plant, Finished Water	232.6	101.1	24-409	100

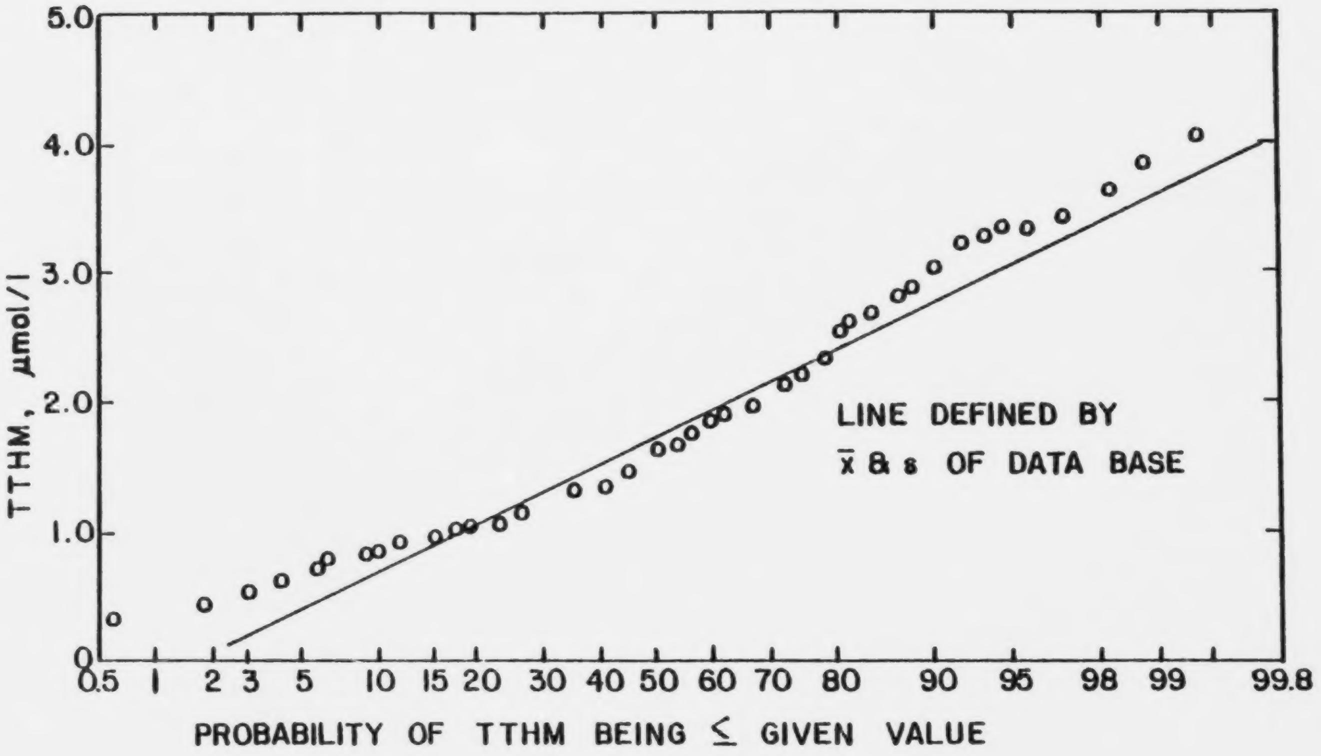

Figure 4. Distribution of total trihalomethane concentrations observed in finished waters in the Fairfax County Water Authority's water distribution system, June, 1975 - May, 1977 ($\bar{x}$ = mean; s - standard deviation.

in determining whether certain data-analysis procedures are valid. Symons et al. (12) reported previously that the data collected during the National Organics Reconnaissance Survey (NORS) involving eighty water supplies from several types of sources were log-normally distributed.

The individual data for finished water samples during June through September from which Table 18 was constructed are shown graphically in Figure 5. In general, the THM concentration in weekly grab samples seemed to increase and decrease similarly at Sites D, E, and F during June and July, 1975. During this period, there did not appear to be a consistent order of THM concentrations (e.g. E>F>D). Often, the concentrations at the treatment plant were greater than at one or more of the distribution system sites. In late July and during August, however, the lowest concentrations were observed at the treatment plant, as one would expect. It should be remembered that during the first year, the samples were refrigerated until the time of analysis and were not dechlorinated, so care must be taken in generalizing about trends in the data because there is no way of knowing whether the total THM formation potential (THM FP) had been reached. What is clear from Figure 5 is the concentration of THM's steadily increased during June and July and began to decrease in late August. The resurgence during early September occurred immediately after a two-day period of heavy rainfall on September 11 and 12.

Figure 6 shows the observed hourly variations in THM's at Sites D, E, and F. One observation evident from this figure is that the variations were more pronounced at Site F during the twenty-four hour period, indicating that the intermediate storage and rechlorination at Cameron Station may have a definite effect. The bihourly variability also suggests that the time of day when sampling occurs will affect the observed THM concentration, but there most likely is no well defined diurnal pattern. It was noted that the average bihourly concentrations on September 11 were significantly greater than the average daily concentrations observed the week of September 10 through 16. Figure 5 shows that concentrations were greatly decreasing during that particular week, but the data certainly suggest that "average concentrations" one might cite for a given system may have an associated high variability which is dependent upon the time of sampling. Another source of variability which should be considered is in the THM analysis itself. The precision of the Bellar-Lichtenberg THM analysis has been shown to be on the order of ±10 percent (13). More discussion about variations in THM concentrations with time of sampling will be presented in a subsequent section.

Table 18 and Figures 7 and 8 show that the highest THM concentrations were observed during the summer months during the first year of the study. Chloroform accounted for about 90 percent of the TTHM concentrations observed on all occasions, $CHCl_2Br$ accounting for most of the remainder. Both $CHBr_3$ and $CHBr_2Cl$ were seldom detected. Figures 7 and 8 show, respectively, the observed variations in TTHM's and $CHCl_2Br$ at the treatment plant during Occoquan-I. A definite trend was evident, the highest concentrations occurred during the summer months and the lowest during the winter. Patterns of TTHM variations at the other finished-water sampling sites were similar to those depicted by Figures 7 and 8. During Occoquan-II, the patterns were different, a fact that will be discussed later.

TABLE 18. VARIATIONS IN TOTAL TRIHALOMETHANE (TTHM) CONCENTRATIONS OBSERVED IN FINISHED DRINKING WATER AT THREE LOCATIONS DURING THE PERIOD FROM JUNE, 1975 THROUGH MAY, 1976
(Values shown are Means ± Standard Deviations)

Sampling Site*	Weekly June-October		Daily September 10-16		Bihourly September 11		Monthly November-May	
	A†	B†	A†	B†	A†	B†	A†	B†
D	2.38 ± 0.63	284 ± 75	1.93 ± 1.06	230 ± 127	3.37 ± 0.26	402 ± 31	1.18 ± 0.35	141 ± 42
E	2.61 ± 0.91	312 ± 109	2.59 ± 0.91	309 ± 109	3.44 ± 0.22	411 ± 26	1.14 ± 0.39	136 ± 47
F	2.63 ± 0.77	3.4 ± 92	2.48 ± 1.23	296 ± 147	3.06 ± 0.54	365 ± 65	1.13 ± 0.39	135 ± 47

* Site D: Water Treatment Plant
Site E: Distribution System, Fairfax County
Site F: Distribution System, Alexandria

† Column A: TTHM, µmol/ℓ; mean ± standard deviation
Column B: $CHCl_3$ Equivalents, µg/ℓ; mean ± standard deviation

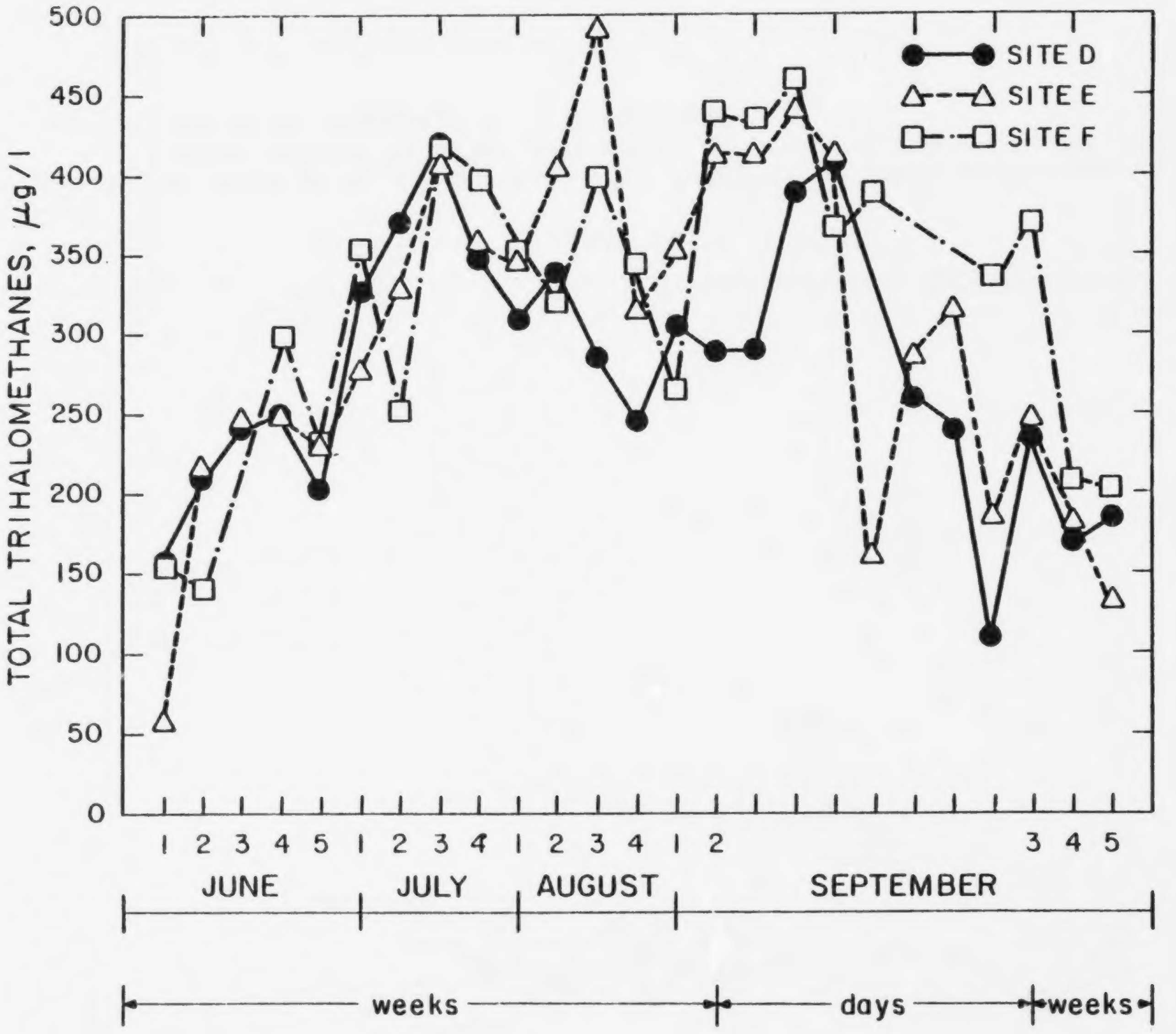

Figure 5. Weekly and daily variations in THM's during 1975 at FCWA's water treatment plant (Site D) and at two distribution system sites 8-10 hours distant from the plant. Samples were not dechlorinated.

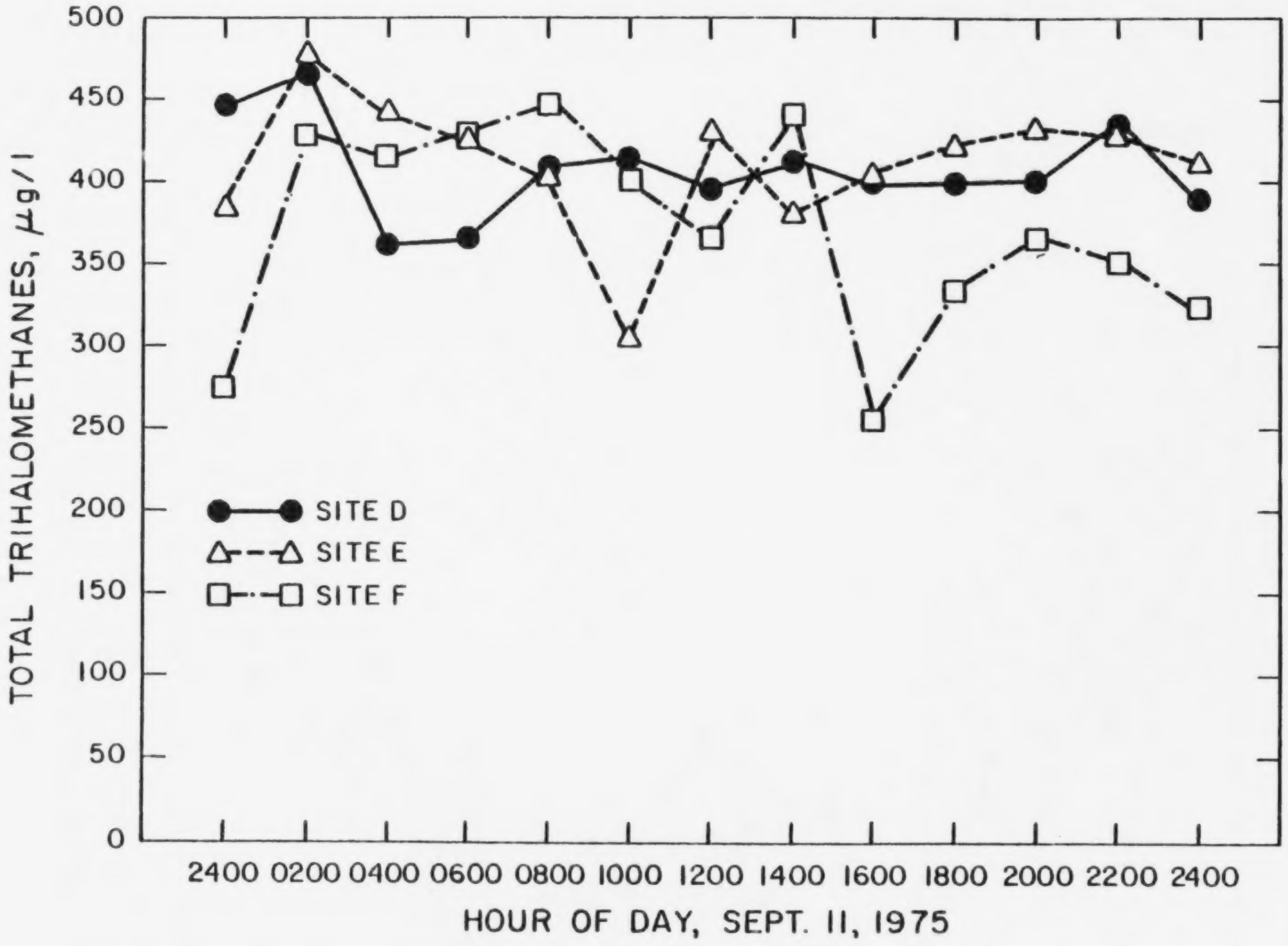

Figure 6. Bihourly variations in THM's one day during 1975 at FCWA's water treatment plant (Site D) and at two distribution system sites 8-10 hours distant from the plant. Samples were not dechlorinated.

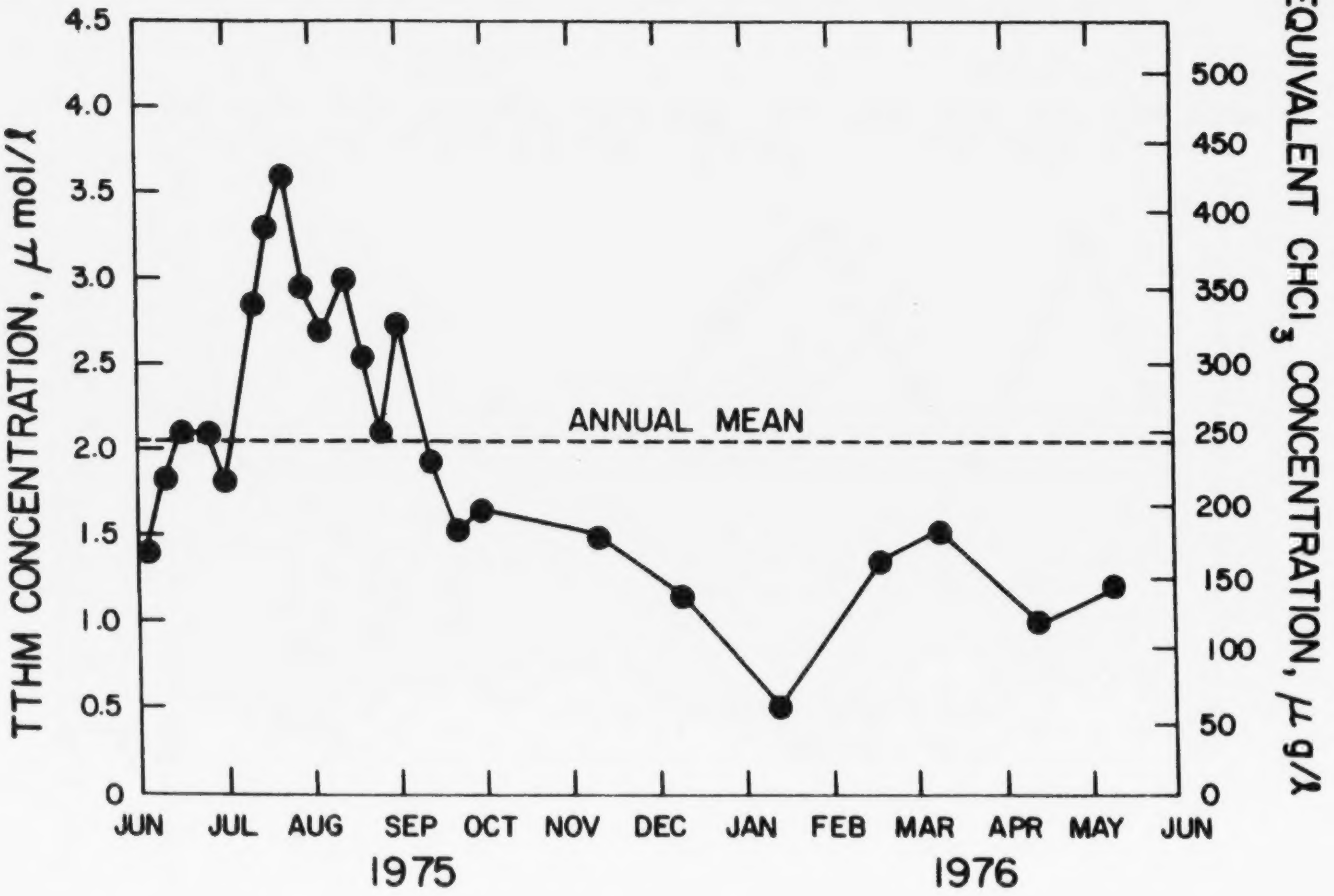

Figure 7. Variations in concentrations of total trihalomethanes in finished water at the water treatment plant (site D) during the period from June, 1975 through May, 1976. Samples were not declorinated.

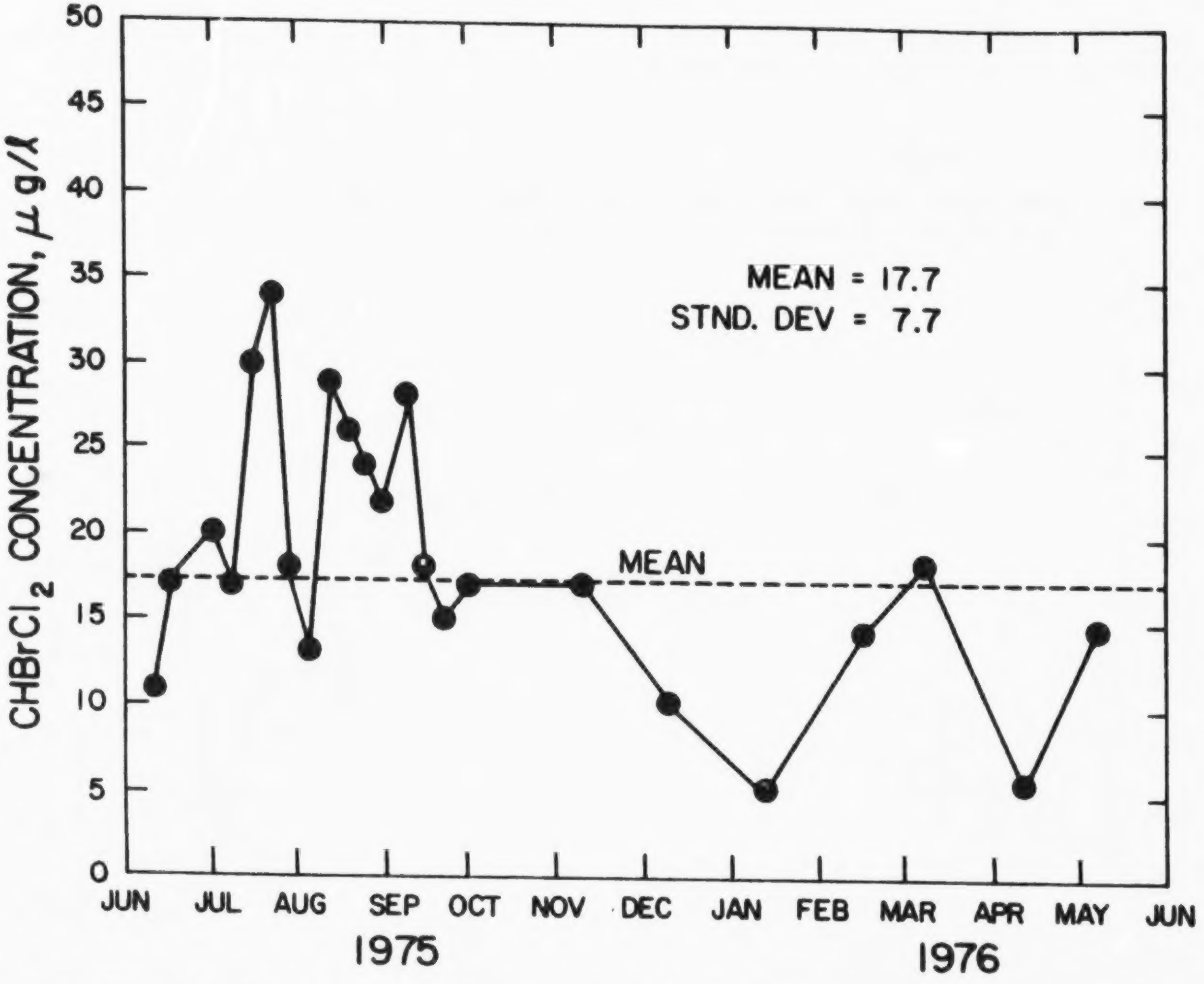

Figure 8. Variations in bromodichloromethane concentrations in finished water at the water treatment plant (site D) during the period from June, 1975 through May, 1976. Samples were not dechlorinated.

Comparison With Other Studies--

Table 19 was prepared to show how the Occoquan-I THM data compared to that obtained during two other EPA-sponsored surveys. The NOMS data displayed in Table 19, was taken from the Federal Register (8), and are those derived from the first of four phases. Similar collection and handling procedures were used during NORS and NOMS-I and best represented those used during Occoquan-I. The TTHM concentrations in Table 19 are summations of the observed concentrations of all THM's in micrograms per liter instead of in micromoles per liter. This method of expressing the data weights the brominated THM's more heavily than the less toxic chloroform and, in addition, is a simpler method for expressing the data than that required to express it in terms of micromoles per liter.

It should be noted that both the NORS and NOMS studies represent a variety of water sources. For example, the NORS study included localities that took their raw water from ground water sources (20 percent), lakes or reservoirs (33 percent), and rivers (47 percent). Too, the data in both the NOMS and NORS studies were conducted in the winter months. From Table 19, it can be seen that while the average TTHM was much higher in the Occoquan study, the maximum values observed in each study were comparable.

The individual data used to compute the values found in the figures and tables presented thus far in this section of the report appear in Appendix C, Tables C-1 through C-11. Some data appearing there have not been discussed thus far in any detail, and a few should be mentioned because they are unusual. For example, Tables C-5 and C-6 show that during the bihourly sampling on September 11, $CHCl_2Br$ appeared only at Site F in Alexandria, Virginia. Chlorine is applied when water is taken from the open storage reservoir during peak demand periods to supplement the supply coming directly from the FCWA plants, but the chlorine supplier is the same for both FCWA and the Virginia-American Water Company in Alexandria. Thus far, no explanation has been found for the more frequent appearance of $CHClBr_2$ at Site F (Tables C-6 and C-7). Finally, note from Table C-7 that 1,2-DCE + CCl_4 appeared most frequently in Bull Run (Sites A and B) and, with one exception, in higher concentrations than were observed elsewhere. Separation of these two volatile organics was not attained until late in the Occoquan-I study when the analytical procedures were modified. No explanations are apparent for the presence of 1,2-DCE and CCl_4 in Bull Run during Occoquan-I, nor for the high concentration (34 μg/1) noted on June 9, 1975, in finished water at the treatment plant (Site D). Neither CCl_4 or 1,2-DCE were observed at Sites E and F.

Occoquan-II: 1976-1977

Frequency and Distribution--

Table 20 shows the frequency the haloforms and other volatile organics appeared in finished water at four finished-water sites. (See Appendix C, Tables C-12 through C-16 for the individual data.) As was true during Occoquan-I, $CHCl_3$ and $CHCl_2Br$ were present in every sample. The concentrations of $CHBr_2Cl$ were always less than 5 μg/1 (usually less than 2), though it was detected from 45-55 percent of the time. Carbon tetrachloride (CCl_4) and 1,2-dichloroethane (DCE) appeared more frequently in finished water than

TABLE 19. COMPARISONS OF HALOFORM CONCENTRATIONS OBSERVED DURING THE NORS, NOMS, AND OCCOQUAN-I STUDIES

Haloform	[a]Concentrations Observed, µg/l [b]NORS Jan-Feb, 1975	 [b]NOMS-I Mar-April, 1976	 [c]OCCOQUAN-I June, 1975-May, 1976
Chloroform			
mean	-	43	246
median	21	27	243
range	nf-311	nf-271	22-495
Bromodichloromethane			
mean	-	18	19
median	6	10	18
range	nf-116	nf-183	<1-39
[d]**Total Trihalomethanes**			
mean	67	68	249
median	27	45	238
range	nf-482	nf-457	40-531

[a] nf=not found

[b] Reference 8, non-dechlorinated samples

[c] Data used for calculations: Weekly values, June 2 - Oct. 8, 1975 and monthly values Nov. 1975 - May, 1976. The average of the daily values during Sept. 9-16, 1975, was considered a "weekly value" and the average of the bihourly values on Sept. 11, 1975, during that week was considered a "daily value." (Three finished-water sites). Samples were not dechlorinated.

[d] Sum of individual THM's in µg/l rather than µmol/l to conform with the proposed interim MCL expression used by EPA

TABLE 20. FREQUENCY OF VOLATILE ORGANICS GREATER THAN OR EQUAL TO ONE MICROGRAM PER LITER AT ALL SAMPLING SITES, JUNE, 1976-MAY, 1977

Site	*Total Obser-vations	$CHCl_3$		$CHBrCl_2$		$CHBr_2Cl$		$CHBr_3$		CCl_4		1,2-DCE	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
C	21	3	14	1	5	0	0	0	0	0	0	0	0
D	21	21	100	21	100	10	48	2	10	4	19	1	5
E	20	20	100	20	100	11	55	0	0	5	25	1	5
F	20	20	100	20	100	9	45	0	0	2	10	1	5
G	20	20	100	20	100	9	45	5	25	2	10	1	5

Site C: Intake, FCWA water treatment facility.

Site D: Finished water, FCWA water treatment facility.

Site E: Distribution system, FCWA's storage yard.

Site F: Distribution system, Alexandria, Virginia.

Site G: Distribution system, Dumfries, Virginia.

*Includes 10 monthly samples and 5 daily samples for each of the other two months. Two samples were collected in June at Sites C and D.

during Occoquan-I, and concentrations as high as 7 and 9 µg/l, respectively, were observed. Recall that it was not until February 8 that DCE and CCl_4 were separated during the analysis, and thereafter low concentrations of CCl_4 began to be detected, especially during March through May, 1977. DCE appeared only in the February samples, and it was detected in all of the finished-water samples. Bromoform ($CHBr_3$) was detected only at Site D at 3 and 1 µg/l on March 7 and 8, respectively.

CCl_4, which is not a product of reactions between organics and chlorine, has been identified in the District of Columbia's drinking water at 5 µg/l (14). The EPA 80-City Study (NORS) showed that CCl_4 was present at 10 locations in concentrations of 3 µg/l or less, and 1,2-DCE (ethylene dichloride) was present in 26 supplies in concentrations ranging from 0.2 - 6 µg/l (12). It also has been found in the New Orleans water supply at a concentration of 8 µg/l (17). The EPA lists both these compounds as industrial contaminants, and CCl_4 has been found in deionized water dosed with commercial chlorine gas in concentrations ranging from about 1 to 40 µg/l (Personal communication, Mr. William M. Blankenship,Technical Advisor,USEPA Region III, Philadelphia).

Table 20 also shows that $CHCl_3$ was detected in raw water only on three occasions (14 percent of the time) during Occoquan-II. This contrasts with the high frequency of detection at Site C during Occoquan-I (62 percent). Note also that $CHBrCl_2$ was the only other volatile organic detected in raw water during Occoquan-II, and that was only on one occasion. Table 21 summarized the significant data concerning THM concentrations observed at each finished-water sampling site during Occoquan-II. It can be seen that the average concentrations at Sites D, E, and F were nearly the same, but at Site G, which is the most distant in the distribution system, the concentrations averaged about 15 percent greater. Also, the average, free-chlorine residuals were lowest there (Table 22), this being especially true during the summer months. The individual data used to calculate the statistics shown in Table 21 are in Appendix C, Tables C-12 through C-16. Those used to calculate the statistics regarding chlorine concentrations are found in Appendix D, Table D-2.

THM Concentrations in Dechlorinated Samples--

During Occoquan-II, duplicate samples were collected on each sampling date and one of them was dechlorinated immediately so that the instantaneous THM concentration could be measured. (This procedure was followed also during NOMS-III to be discussed briefly in a subsequent paragraph). The results of these analyses are summarized in Figure 9 which shows the mean THM concentrations and standard deviations associated with those means at the four finished-water sites sampled during Occoquan-II. The significance of this particular THM measurement at any location is that the instantaneous concentration more closely approximates the THM level of exposure to the consumer than does the "terminal" THM concentration, i.e., that which is obtained when reactions are allowed to go to completion, at least under the constraints of the available chlorine and reactable organic matter present at the time of sampling.

In Figure 9, the bars representing the sampling stations were arranged from left to right in increasing order of the hydraulic travel time from

TABLE 21. STATISTICAL COMPARISONS OF TRIHALOMETHANE [*]CONCENTRATIONS IN FINISHED WATER AT FCWA'S TREATMENT PLANT AND AT THREE SITES IN THE DISTRIBUTION SYSTEM: MAY, 1976-June, 1977

Site	Statistic	$CHCl_3$, μg/l		$CHCl_2Br$, μg/l		TTHM, μg/l		TTHM, μmol/l	
		[†]Terminal	[†]Dechlor.	[†]Terminal	[†]Dechlor.	[†]Terminal	[†]Dechlor.	[†]Terminal	[†]Dechlor.
[††]D	mean	147	94	19	14	164	110	1.35	0.84
	median	128	83	20	13	153	98	1.12	0.79
	range	64-240	25-164	10-28	5-25	73-265	41-181	0.59-2.16	0.32-1.47
	stnd.dev.	62	40	7	7	77	44	0.55	0.36
E	mean	146	99	22	15	166	100	1.37	0.93
	median	128	70	23	16	151	100	1.26	0.82
	range	70-265	38-191	9-45	5-24	79-285	43-202	0.64-2.34	0.35-1.71
	stnd.dev.	61	51	10	7	64	54	0.53	0.45
F	mean	144	101	24	15	173	110	1.35	0.94
	median	139	93	22	15	164	107	1.33	0.86
	range	66-249	38-179	9-50	3-28	75-220	41-200	0.6-2.22	0.35-1.63
	stnd.dev.	54	45	12	7	66	49	0.50	0.40
G	mean	161	147	21	18	183	164	1.56	1.42
	median	151	145	22	19	167	165	1.36	1.35
	range	94-306	41-310	8-38	6-28	103-329	47-330	0.84-2.70	0.38-2.72
	stnd.dev.	63	64	8	7	67	68	0.55	0.59

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[*] One sample per month except during Aug. 1976 & Mar. 1977. For those months, the average of 5 daily samples was included as the monthly value for the analysis.

[†] Terminal: Samples allowed to react to completion before analysis;
Dechlor: Samples dechlorinated with potassium ferrocyanide at time of collection.

[††] Statistics computed without including the one extremely high terminal $CHCl_3$ value (858 μg/l) observed during the week of daily sampling in August.

TABLE 22. COMPARISONS BETWEEN TRIHALOMETHANE AND CHLORINE CONCENTRATIONS OBSERVED AT FCWA'S TREATMENT PLANT AND AT THREE SITES IN THE DISTRIBUTION SYSTEM: MAY, 1976 - JUNE, 1977

Site	Statistic	TTHM, µmol/l		Chlorine Residual, mg/l	
		Terminal	Dechlorinated	Total	Free
D	mean	1.35	0.84	2.7	2.5
	median	1.12	0.79	2.5	2.5
	range	0.59-2.16	0.32-1.47	2.1-4.2	1.9-3.5
	stnd. dev.	0.55	0.36	0.6	0.5
E	mean	1.37	0.93	2.5	2.2
	median	1.26	0.82	2.5	2.2
	range	0.64-2.34	0.35-1.71	1.2-2.9	1.1-3.2
	stnd. dev.	0.53	0.45	0.3	0.3
F	mean	1.35	0.94	1.9	1.6
	median	1.33	0.86	1.9	1.6
	range	0.6 -2.22	0.35-1.63	0.8-2.4	0.7-2.5
	stnd. dev.	0.50	0.40	0.6	0.5
G	mean	1.56	1.42	1.1	0.9
	median	1.36	1.35	1.0	0.8
	range	0.84-2.70	0.38-2.72	0.2-2.7	0.1-2.3
	stnd. dev.	0.55	0.59	0.7	0.6

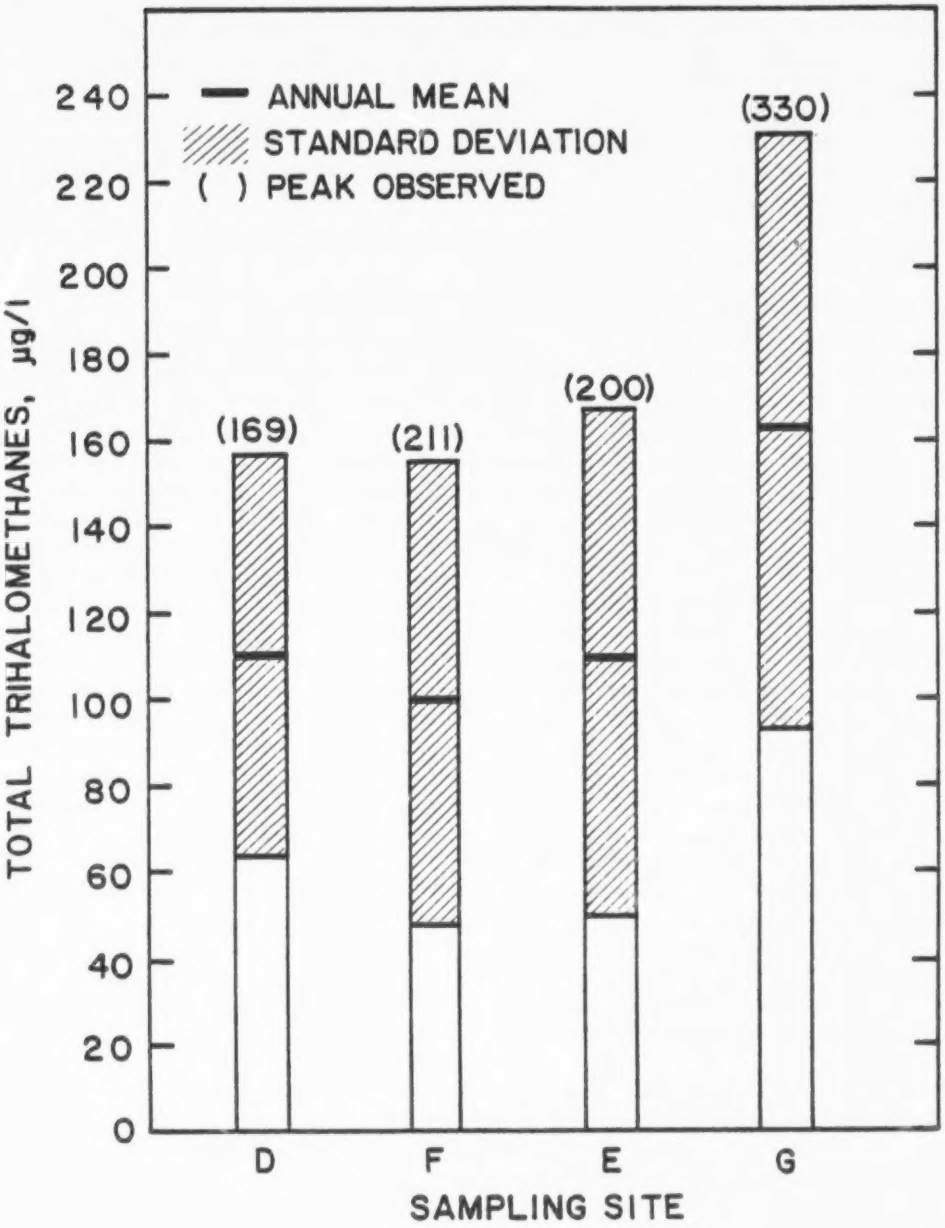

Figure 9. Instantaneous TTHM concentrations in dechlorinated finished water at four sites during Occoquan-II. (One standard deviation on either side of the mean is shown for each site.)

the treatment plant (Site D). These were, for Sites F, E, and G, 8, 10, and 13 hours, respectively. (The intermittent reservoir in Alexandria was ignored in the calculation of travel time for Site F since it contributed flow only after 4:00 p.m., a later time than when all samples were collected there). It seems clear from the data that the only significant difference, as was the case for the samples which were not dechlorinated (Table 21), was at Site G where the mean THM concentrations averaged about 35 percent greater than at Sites D, E, and F. Table 21 summarizes the statistical information shown graphically in Figure 9.

Comparison With Other Studies--

Tables 23 and 24 summarize the measured concentrations of $CHCl_3$, $CHCl_2Br$, and TTHM (as µg/l) observed at all finished-water sampling sites during Occoquan-II and compare the statistical data to those obtained during various phases of the NOMS study (8) of 113 cities. Samples collected during NOMS-II, NOMS-III, and Occoquan-II were treated similarly in that samples stood for a sufficient time at room temperature before analysis to ensure that the reactions could go as far toward completion as the concentrations of the reactants would permit. Some, of course, may have been limited by the availability of chlorine. In both NOMS-III and Occoquan-II, a second sample was collected on every sampling date and dechlorinated immediately. On the average, the instantaneous THM concentration was 72 percent of the "terminal" concentration during Occoquan-II but only 45 percent in NOMS-III. However, NOMS-III was conducted during the period from November, 1976 through January, 1977, when the water temperature was low, a condition which would cause the haloform reaction to proceed more slowly than during warmer weather. In January during the Occoquan-II study, the concentrations of THM's in the three of the four dechlorinated samples were only 45-48 percent of the terminal concentration. Figure 10 shows the observed relationship between the temperature and $CHCl_3$ in dechlorinated samples expressed as a percentage of the terminal concentration. There is considerable scatter in the data which was caused by a variety of factors (reactant considerations, time of travel to sampling site, time elapsed since chlorine added, etc.) but the general trend is obvious: the colder the water, the smaller the percentage of the terminal $CHCl_3$ concentration at the tap. There was no well-defined relationship between the individual instantaneous THM concentrations and temperature, however. (See Figure 11.)

Note from Table 23 that the high TTHM value was nearly 900 µg/l. This value was observed on August 9 at Site D on the first of the five consecutive-day sampling programs. A second sample collected within minutes of the first showed a concentration of 869 µg/l $CHCl_3$. A search of the water treatment plant records failed to turn up an irregularities in the normal plant operations, and the other water quality data routinely collected at the plant were not unusual in any respect. The cause of this event is unknown, and it is difficult to speculate how concentrations of organic carbon might be so high at that one period. The phenomenon was never again observed.

It should be noted that Occoquan-II sampling represented an entire year whereas NOMS-II and III were conducted during three-month periods in two different seasons, and the data may well reflect seasonal variations. One thing is clear, though: as was true for THM concentrations observed during

TABLE 23. COMPARISONS OF HALOFORM CONCENTRATIONS OBSERVED DURING THE NOMS AND OCCOQUAN-II STUDIES.

	[a]Terminal Concentrations Observed, µg/l		
Haloform	[b]NOMS-II May-July, 1976	[b]NOMS-III Nov. 1976-Jan. 1977	[c]OCCOQUAN-II June 1976-May 1977
Chloroform			
mean	83	69	152
median	59	44	136
range	nf-470	nf-540	[d]40-858
Bromodichloromethane			
mean	14	11	21
median	18	17	22
range	nf-180	nf-125	3-50
Total Trihalomethanes			
mean	117	100	173
median	87	74	164
range	nf-784	nf-695	43-889

[a] "Terminal": reactions allowed to go to completion. nf=not found

[b] Reference 8

[c] Monthly values were used for calculations of means and medians. The Aug. 1976 and Mar. 1977 values were averages of analyses on five consecutive days (four finished-water sampling sites). These daily values were considered when stating the ranges, however.

[d] The high value was nearly three times that of the next highest. Without it, mean = 116, median = 115, high = 329.

TABLE 24. COMPARISONS OF HALOFORM CONCENTRATIONS IN DECHLORINATED FINISHED WATER SAMPLES COLLECTED DURING THE NOMS AND OCCOQUAN-II STUDIES

Haloform	[a]Observed Concentrations, μg/l, in Dechlorinated Samples [b]NOMS-III	 [c]OCCOQUAN-II
Chloroform		
mean	35	109
median	22	97
range	nf-200	19-310
Bromodichloromethane		
mean	9	15
median	6	16
range	nf-72	3-28
Total Trihalomethanes		
mean	53	125
median	37	115
range	nf-295	25-330

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[a] nf=not found

[b] Reference 8

[c] Monthly values were used for calculations of means and medians. The Aug. 1976 and Mar. 1977 values were averages of analyses on five consecutive days (four finished-water sampling sites). These daily values were considered when stating the ranges, however.

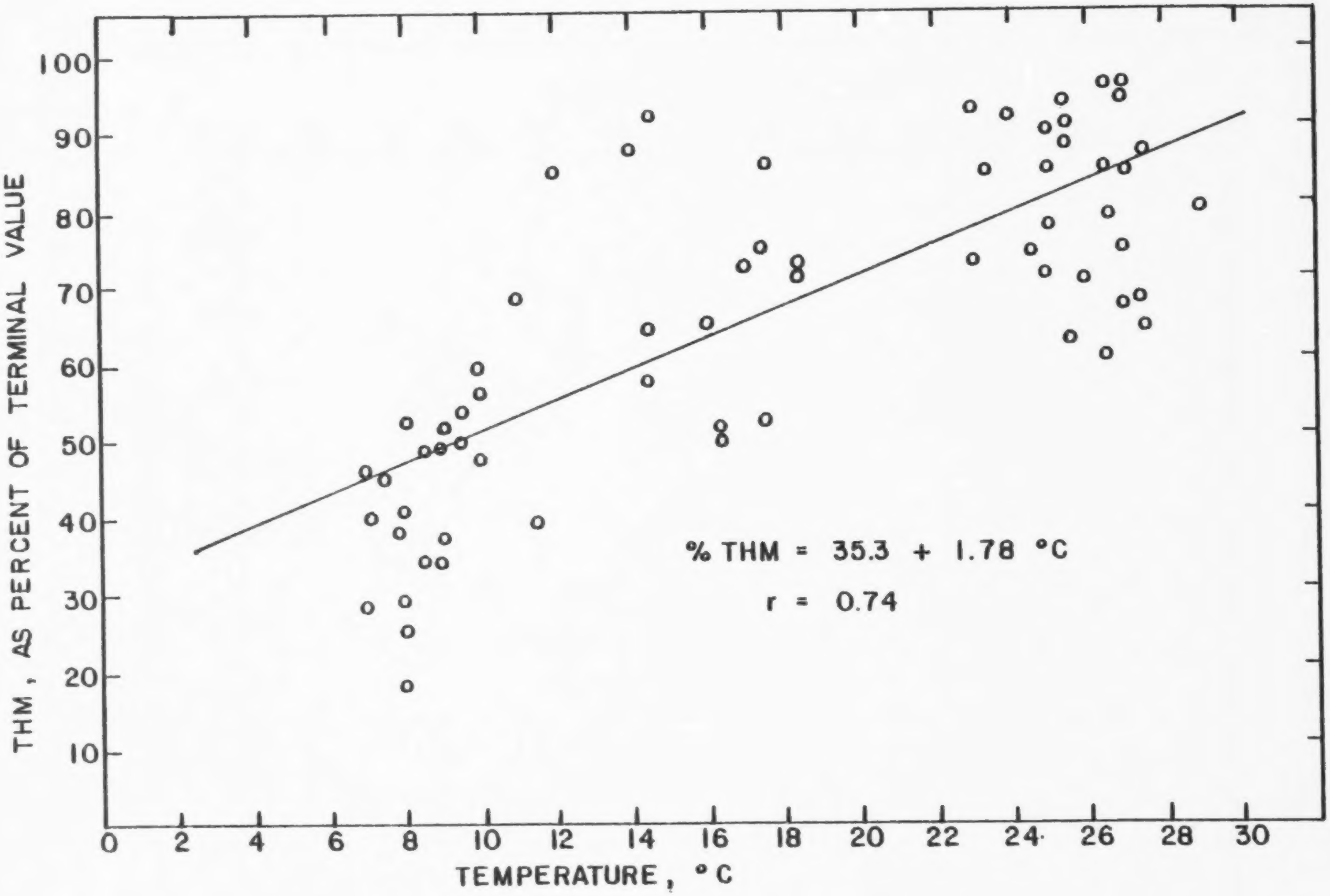

Figure 10. Relationship between finished-water temperatures and concentrations of trihalomethanes in dechlorinated samples, expressed as a percentage of terminal trihalomethane concentration.

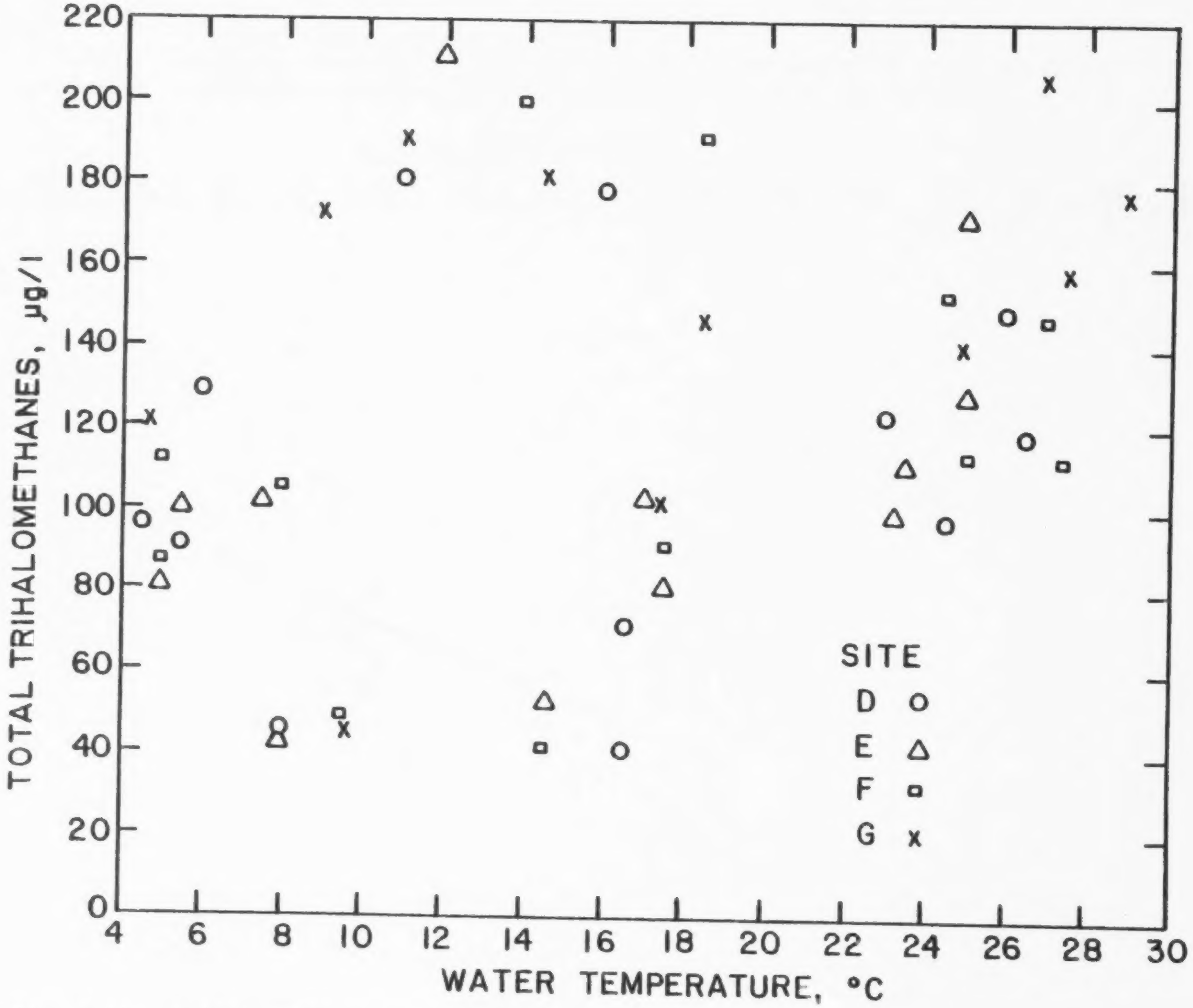

Figure 11. Relationship between instantaneous TTHM concentrations and water temperatures at the treatment plant (Site D) and three distribution system sites.

Occoquan-I, the FCWA's finished water consistently contained higher mean concentrations of THM's than was found in the NOMS studies. Finally, Tables 23 and 24 compare the concentrations of only the two most abundant THM's. Appendix Tables C-12 through C-16 provide the data which could be used to calculate similar statistical information for other volatile organics. These values were not included in Tables 23 and 24 because of their infrequent occurrence in FCWA's finished water.

Total Organic Carbon (TOC)--

A requirement of the contract regarding Occoquan-II was that TOC concentrations in the samples were to be determined. The individual TOC data are displayed in Appendix C, Tables C-12 through C-16. Raw water TOC concentrations averaged 4.2 mg/l (range 2.4 - 11.5). Until April, 1977, all TOC analyses were conducted with the Beckman 915A instrument (20 mg/l full-scale deflection). In April and May, the Dohrmann/Envirotech Model 54 analyzer, which permitted analyses with parts per billion accuracy, was used. For all data pertaining to finished-water TOC concentrations, the mean was 2.4 mg/l (range 1.0 - 7.0). During the last two months when the more sensitive instrument was used, the average was 1.4 mg/l (range 1.1 - 1.6). An attempt was made to correlate the finished-water TOC concentrations with the THM concentrations, and the correlation was extremely poor.

Young and Singer (15) noted similar results during a study of THM's produced during treatment of water from two separate reservoirs in North Carolina. They noted that "... there is little seasonal variation in [nonvolatile] TOC (NVTOC) levels in raw water. However, fluctuations in the amount of $CHCl_3$ produced during water treatment suggest that it is difficult to predict the finished water concentration on a given day solely on the NVTOC concentration." Their reasoning that "NVTOC is a collective measure of all organic constituents, only a few of which are $CHCl_3$ precursors" provides the explanation for the lack of linear correlation between THM's and TOC in the Occoquan Project.

In the Occoquan Reservoir, or in any other for that matter, the organic matter entering several miles above the dam tends to be well stabilized by bacterial degradation by the time it reaches the raw water intake. While there no doubt are biologically mediated organic compounds available that will react to form haloforms, most of the TOC merely exerts a chlorine demand or forms chlorosubstituted organics other than trihalomethanes. One can speculate that the TOC entering rivers by way of runoff is likely to be less stabilized and, hence, more reactive in producing THM's. Wood and DeMarco (16) have reported that TOC data did not consistently correlate with the THM formation potential of well water from humate-laden aquifers in Florida (av. TOC, 9-10 mg/l). They also reported that only about 35 percent of the TOC could be removed by coagulation, flocculation, clarification, and filtration combined. At FCWA, TOC removals varied considerably during treatment, but averages were from 50 to 70 percent. Still, concentrations of TOC greater than 1.0 mg/l were consistently found in the finished water.

Comparison of Occoquan-I and Occoquan-II THM's

Table 25 presents a comparison of the average TTHM concentrations (and other statistics) observed during Occoquan-I and Occoquan-II. The data are grouped by intervals of three months to demonstrate, to some degree, the seasonal variations that occurred. It is obvious that there were seasonal variations during both years, but the patterns of fluctuation differed. In 1975-1976, the highest concentrations occurred during the summer, but during 1976-1977, the highest concentrations were not observed until the fall. Furthermore, the average high concentrations observed during Occoquan-I were approximately a third greater than those observed during Occoquan-II.

In Figure 12, the average THM concentrations observed at each finished-water site during the two-year study are depicted along with the annual mean for all sites. The means at each site were calculated by averaging monthly values. If analyses were performed weekly, then the monthly average was calculated from four or five values. When the frequency was daily, an average was obtained and considered to be a weekly value. Bihourly samples were averaged to give a single daily value. From Figure 12 one can see that the annual average THM concentration was slightly lower the second year of the study. During both Occoquan-I and Occoquan-II, concentrations of THM's in non-dechlorinated samples from the distribution system were both less than and greater than those in samples from the treatment plant. There was no definite pattern.

Several facts must be kept in mind if Figure 12 is to be properly interpreted. First, the estimated hydraulic travel time to Site E from the New Lorton Plant is two hours greater than to Site F, but there is intermediate storage at Site F and the water is rechlorinated at the time it reenters the distribution system. Second, Site G, though furthest from the treatment plant, receives water only from the Occoquan Plant (See Table 2). The other two sites receive a mixture of water from all three of FCWA's treatment facilities. If there is to be a direct comparison of THM's found at Sites D, E, and F with those at G then an assumption must be made that the THM concentrations in Occoquan Plant water were similar to those in the mixture. The assumption is probably valid since all three plants have a common raw-water intake. Third, data previously presented in this report and summarized in Table 25, clearly show that the THM concentrations were highly variable from season to season. Even the bihourly analyses showed that there was considerable variation in THM concentrations in water from the same site. Therefore, the slight differences in average THM concentrations shown by Figure 12 are not statistically different because the standard deviations are so high. It appears that the THM concentrations in non-dechlorinated samples could have been taken as representative of those in the distribution system.

It is true that the sampling frequency was greater for part of Occoquan-I (during June-October), but the differences observed during the two phases of the study are more likely related to differences in water quality in the two years of the study. The second year was extremely dry, and the water quality at the dam site improved. The rainy season did not begin until October, 1976, and it was in October and November that the highest TTHM values were observed.

TABLE 25 . A *COMPARISON OF TOTAL TRIHALOMETHANES** IN FINISHED DRINKING WATER BY THREE MONTH PERIODS DURING THE OCCOQUAN-I (1975-1976) AND OCCOQUAN-II (1976-1977) STUDIES

Period	No. of Analyses		Mean Conc., μmol/1		Concentration Range, μmol/1		Standard Deviation μmol/1	
	OCC-I	OCC-II***	OCC-I	OCC-II	OCC-I	OCC-II	OCC-I	OCC-II
June-Aug.	38	13	2.43	1.27	0.48-4.06	0.93-1.79	0.75	0.30
Sept.-Nov.	20	12	2.11	1.82	1.08-3.56	0.81-2.70	0.74	0.59
Dec.-Feb.	9	12	0.84	1.60	0.33-1.25	1.02-2.02	0.37	0.33
Mar.-May	9	12	1.13	0.92	0.90-1.37	0.60-1.51	0.17	0.27

*Daily samples collected during both phases were averaged to give a single value to be used in the analysis. The average bihourly samples during September 11, 1975 were averaged and considered as one value in calculating the average weekly value for September 9-16, 1975 (Occoquan-I).

**TTHM's in non-dechlorinated samples.

***The data obtained during the 5-day periods in August and March were averaged to give a single value so that quarterly averages would not be biased. Therefore, the total individual numbers of measurements are greater than the numbers shown in the table.

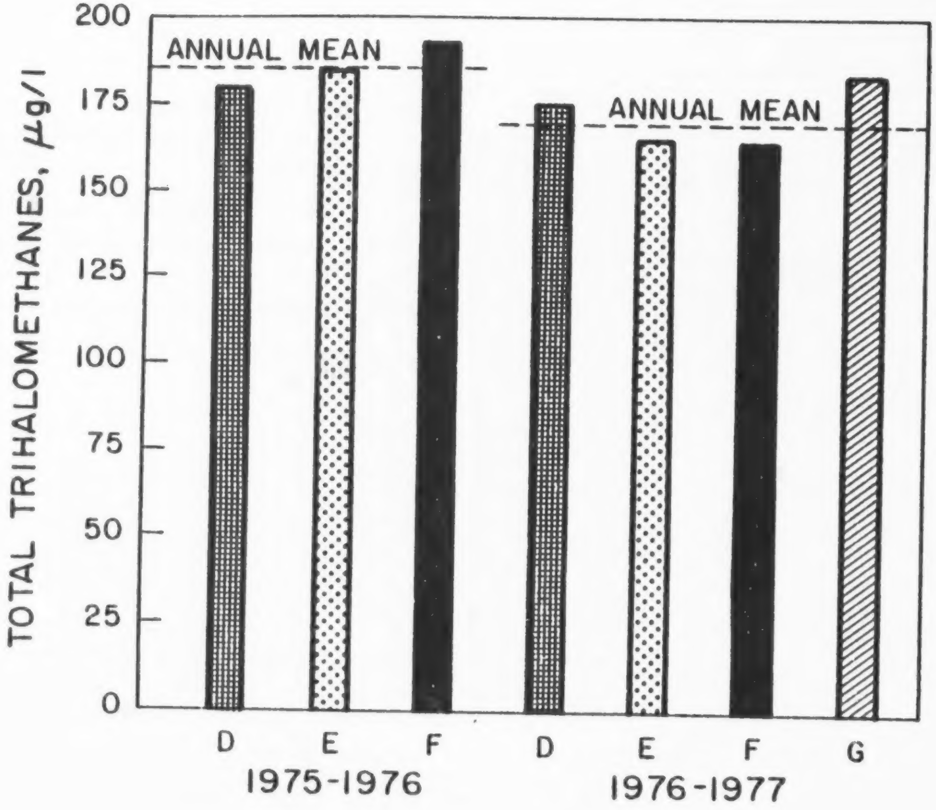

Figure 12. Annual Mean TTHM concentrations in finished water (not dechlorinated) at the treatment plant (Site D) and at sites in the distribution system during Occoquan-I and Occoquan-II.

Data Selection for Determining an Average THM concentration

The proposed interim regulations for organic compounds (8) describe methods to be followed in determining the average THM concentration for a given system. A minimum of five samples is to be taken quarterly: no more than 20 percent from the treatment plant and the rest from the distribution system, 20 percent of which must be from extreme points in the system. The quarterly averages of these samples provide the basis for calculating the yearly average.

Figure 13 shows the results of an analysis carried out with the Occoquan-II data base. The monthly samples (or average of five days in March and August when analyses were on a daily basis) were grouped in three combinations for calculating the quarterly averages. First, the THM concentrations for January, April, July, and October at each of the sites (D, E, F, and G) were averaged. Then, those for February, May, August, and November were averaged; and finally, those for March, June, September, and December were averaged. As can be seen in Figure 13, the yearly averages that would be obtained by computations with the three groups of "quarterly data" differ by as much as 40 μg/l, and two of the three group averages deviate significantly from the annual mean of pooled data from all sites. This analysis considered the THM's only in undechlorinated samples, which probably closely represents the "terminal" TTHM value that could have developed. A similar analysis was conducted with the data for TTHM concentrations in dechlorinated samples. The three "annual means" were 127, 142, and 105 μg/l for the three arrangements of monthly samplings shown in Figure 13 (corresponding to Annual Mean -I, -II, and -III, respectively). The annual mean for all data pooled was 125 μg/l. It is evident that these quarterly averages differed as much as those used in the previous calculations.

These results point out a potential bias that both the utilities and regulatory personnel should be aware of. There is no specific recommendation that can be made based on data derived during this study, though perhaps some scheme might be devised for compositing several samples over at least a 24-hour collection period. However, even that approach, if it were technically feasible and practical, would not be sufficient to compensate for the extreme variability that was observed.

Relationships Between Finished-Water THM's and Raw Water Quality

An Analysis of all available pertinent water-quality data collected routinely by FCWA and the Occoquan Watershed Monitoring Program was undertaken to determine if some correlations could be made between raw-water quality and finished-water THM concentrations. This study was undertaken because the variations in THM concentrations appeared to be of a seasonal nature, both during Occoquan-I and Occoquan-II. The need for such a study became even more apparent when it became evident that the seasonal variations during the two years of the entire study did not follow the same trend, a fact discussed in the preceding section.

Theoretical Considerations--

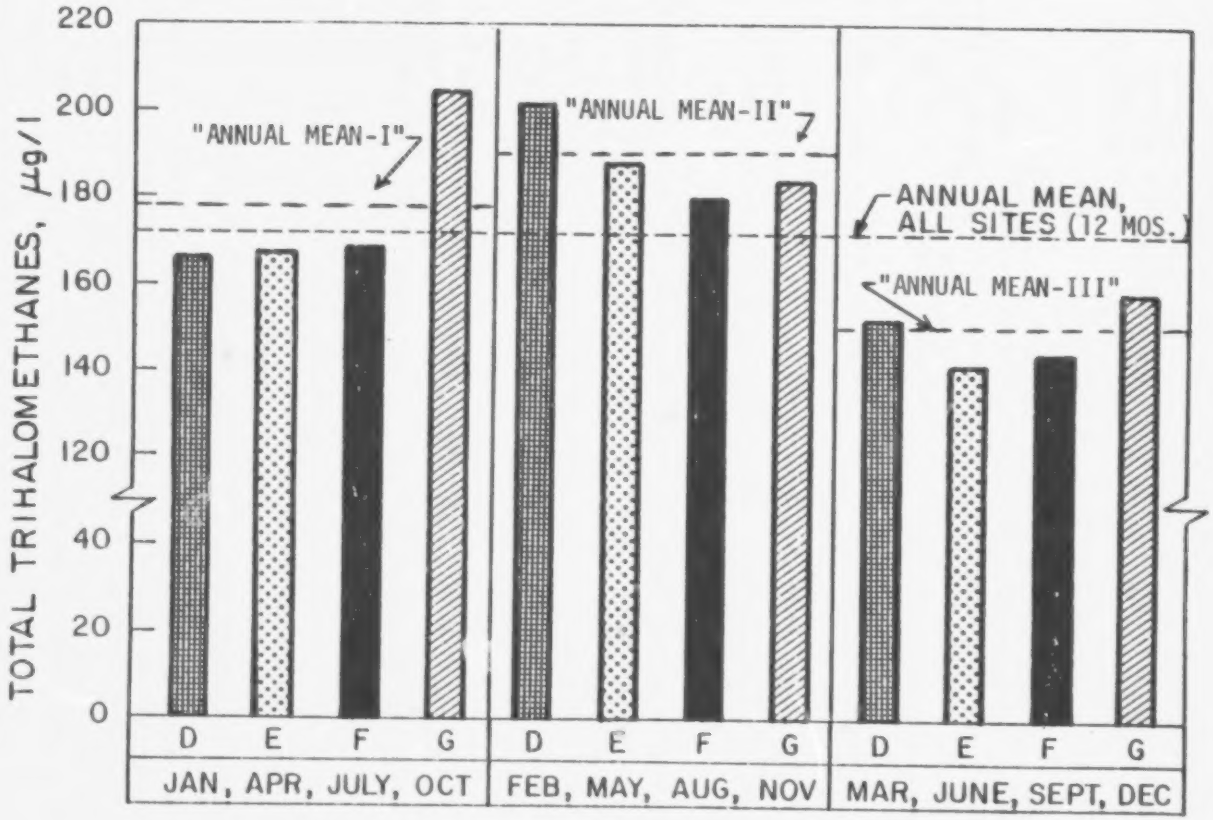

Figure 13. Differences in the "annual mean" TTHM concentration made possible by grouping the Occoquan-II data in three different ways. The twelve monthly average TTHM concentrations (not dechlorinated) at the four finished-water sampling sites were arranged in three different "quarterly groups" which were then averaged. (These are designated Annual Mean-I, -II, and -III). The annual mean concentration of the pooled monthly average TTHM concentrations measured at each site (12 each) is also shown.

Some clue as to which water-quality parameters may be important is given by an examination of the equation for the haloform reaction: In word form, the reaction can be stated as follows:

halogen + precursor organics → haloform + other organics

In more precise chemical form, the equations that illustrate the overall reaction, using chlorine as the halogen (in its hypohalous acid form) are:

$$CH_3COR + 3HOCl \rightarrow CCl_3COR + 3H_2O \qquad [1]$$

$$CCl_3COR + H_2O \rightarrow RCOOH + CHCl_3 \qquad [2]$$

The organics in equation [1] are the precursors and are thought to be compounds containing acetyl groups or others, like secondary alcohols, that can be oxidized to form acetyl groups. Rook (9) first demonstrated that the naturally occurring humates could serve as precursor organics. Recently, Thompson (16) and Barnes (19) showed that laboratory cultures of algae produce an abundance of THM precursors, especially during their active-growth stages. Chlorine, of course, is the other necessary reactant, and it is present in abundance during routine water treatment.

Other factors are known to affect the haloform reaction, especially the rate. Obviously, temperature would affect the rate according to Arrhenius' rule, but pH affects not only the rate but also the absolute yield of haloforms. Reaction [2], the hydrolysis step, is highly dependent on pH. [Morris (20) has presented excellent discussion of the haloform-reaction chemistry for those who wish to have a more thorough understanding.]

It seems, then, that during normal water treatment operations, provided there is adequate time for all reactions to go to completion, the maximum THM concentration one might expect in finished water would be a function of at least four variables: 1) the concentration of precursor organics in raw water, 2) the chemical nature of the precursors (i.e., whether the appropriate functional groups are present), 3) the quantity of chlorine applied during water treatment, and 4) the pH of the water during or after treatment when chlorine is present. Some factors that should reflect the availability of THM precursors in raw water have been listed in Table 26 along with a discussion of the ways they might contribute.

Analytical Approach--

All the available data were accumulated and analyzed by a series of statistical procedures to determine if some multiple-regression expression could be developed to relate finished-water TTHM concentrations to direct or indirect measures of water quality. The procedures chosen were on available computer programs at VPI & SU as parts of a statistical analysis system (SAS). The programs included a "backward elimination routine," a "stepwise elimination routine," and a determination of maximum R^2 values (R = correlation coefficient in a regression analysis). Once the best-fit to the data was obtained, an analysis known as the "Press," was applied to the multiple-regression equation to determine if the equation was truly

TABLE 26. PHYSICAL, CHEMICAL, AND HYDROLOGICAL FACTORS THAT MAY ALTER RAW WATER QUALITY AND SUBSEQUENT TRIHALOMETHANE CONCENTRATIONS IN FINISHED DRINKING WATER

Indicator	Possible Significance
Reservoir Turbidity & Color, Rainfall & Reservoir Stage, Raw-Water Chlorine demand	Increases would indicate influx of land runoff or reservoir destratification, both of which should increase THM-precursor availability.
Reservoir Surface pH and Dissolved Oxygen Concentrations (during daylight hours); Chlorophyll-a Concentrations	Increased algal activity would increase both pH and dissolved oxygen and provide THM precursors through the excretion of extracellular products and by providing cell mass.
Reservoir-Bottom Dissolved Oxygen Concentrations	When less than 0.5 mg/l, or about 5% saturation, anaerobic decomposition of organic matter in sediments and water would produce THM precursors.
Raw-Water Total Organic Carbon & Carbon Chloroform Extracts	Both are indirect indicators of the presence of potential THM precursors.

predictive and, hence, a "model" of the system. It is beyond the scope of this report to provide details of the statistical package used in the computer analysis, but the significant results are discussed in the following paragraphs.

Correlations between TTHM's and other available data-- Each of the water-quality parameters and other data that might be useful in predicting the TTHM concentration in finished water were tested for correlation by a simple, linear least-squares regression analysis. Both Occoquan-I and Occoquan-II data were used in the analysis, but only the average TTHM concentrations at Sites E and F, which were common to both years of the study, were considered. Concentrations at Site D were, at times, lower than at Sites E and F (especially in winter) because there was not always sufficient time for the haloform reaction to approach completion. Site G was not included because it was not sampled during Occoquan-I. Table 27 summarized the linear regression coefficients found to be associated with the various analyses. One precaution which should be interjected at this point is that a low correlation coefficient obtained by a simple linear regression analysis does not preclude the appearance of the associated variable in a multivariant equation.

It is obvious that raw water total organic carbon (TOC) and carbon chloroform extract (CCE) concentrations were not highly correlated with the terminal TTHM concentrations. It is likely that the nature of the organic compounds change with time during the year and not all the TOC (or CCE) will enter the haloform reaction. The high correlations with temperature and chlorine demand and dose were not surprising in light of the observed seasonal variations in TTHM concentrations previously discussed. Temperature data were not included in the multiple regression analysis, however, because the THM concentrations considered were the terminal concentrations, or at least, those in samples that had not been dechlorinated. Also, the high positive correlation more likely reflects the improved quality of the reservoir in the winter.

The pattern of TTHM variations in relation to those for chlorine (applied and residual) are shown in Figure 14. The chlorine demand was calculated by subtracting the total residuals observed at the tap from the dose applied, both during pre- and post-chlorination, at the treatment plant. The general pattern is obvious: the chlorine demand fluctuated in approximately the same manner as did the TTHM concentrations. The dose applied, as shown in Figure 14, is the weighted averaged dose at all three of the FCWA treatment plants (discussed in Section 1). The chlorine demand of Occoquan Reservoir water increases during the summer because reduced iron and manganese are both present in high concentration, but, apparently, the available organic compounds, which also exert a chlorine demand, are high THM-yielding precursors. The relationship apparently is a complicated one and is not adequately described by a simple relationship between TOC and chlorine demand or THM concentration. Even color and turbidity did not correlate well. Young and Singer (14) also reported poor correlations between color and THM's.

It certainly would be convenient for the treatment plant personnel to be able to substitute some easily measured water quality charactersitic for the THM analysis. However, no reliable surrogate could be found among the

TABLE 27. RESULTS OF LINEAR LEAST SQUARES REGRESSION ANALYSES BETWEEN FINISHED-WATER TRIHALOMETHANE CONCENTRATIONS AND RAW WATER QUALITY

Parameter	Correlation Coefficient	Number of Observations
Secchi disk, in.	0.14	21
Color units	0.20	36
Reservoir stage, ft.	0.24	36
Turbidity, JTU's	0.25	37
TOC, mg/l		
Surface	0.25	21
Bottom	0.46	20
CCE, μg/l	0.28	11
Dissolved oxygen, % saturation		
Surface	0.35	19
Bottom	0.75	19
Rainfall, in./mo.	0.54	37
pH, surface	0.57	24
Temperature, surface, °C	0.75	22
*Chlorine demand, mg/l	0.75	37
Chlorine applied, mg/l	0.75	37

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* Calculated by subtracting the chlorine residual from the chlorine dose applied at the treatment plant

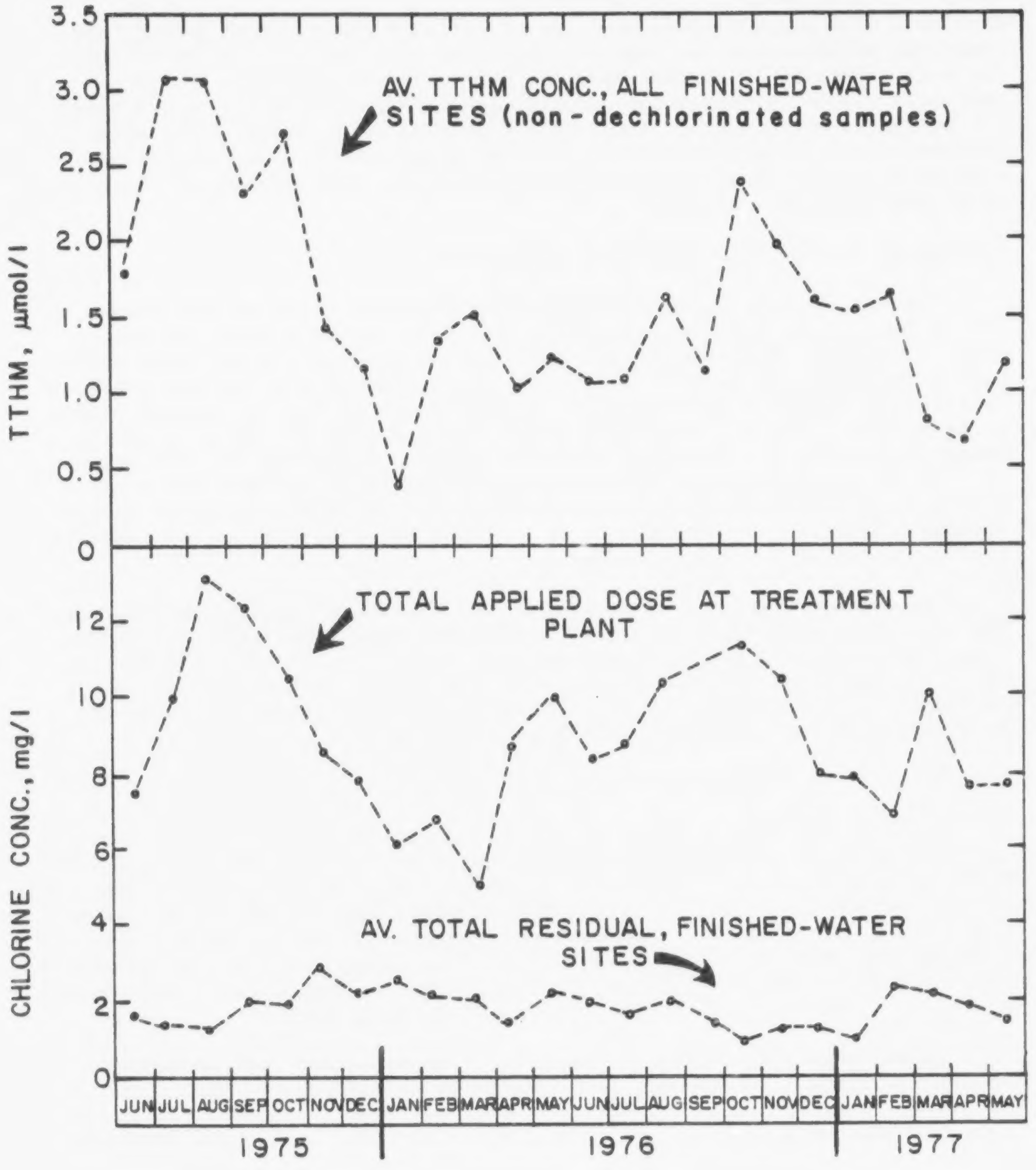

Figure 14. Variations in TTHM concentrations, chlorine dose, and chlorine residuals in finished waters, June, 1975 - May, 1976.

available Occoquan Reservoir data except, perhaps the chlorine demand test. Even that relationship was only moderately well described by a linear relationship. Perhaps it is fallacious to expect that the myriad of complex variables affecting both water quality and the trihalomethane-forming chemical reactions could ever be adequately described by a simple linear relationship. That possibility is attractive, nevertheless, and perhaps one eventually can be found that is applicable, if not universally, at least to one particular treatment plant.

Results of the Multiple Regression Analysis--

The multiple regression analysis identified two water-quality characteristics (dissolved oxygen concentration and chlorine requirement) and two hydrology-related characteristics (rainfall and reservoir stage) that were highly correlated in formulating an empirical relationship with the observed finished-water TTHM concentrations. A description of the statistical procedures and the "best-fit" equations which resulted from the analysis are found in Appendix E. The terms included in these equations are indicators of: 1) algae growth(dissolved oxygen at the reservoir surface, which often was supersaturated), 2) the influx of THM precursors from the surrounding watershed (rainfall and stage), 3) the overall water quality in the reservoir (chlorine applied and chlorine demand).

The equations which were developed, while serving to describe the data, did not prove to be true models of the system because they were not predictive (See Appendix E for the explanation). More data than are available are needed to calibrate and verify any model, and it may be that it will be impossible to account for all the conditions that influence THM production in a surface-water source like the Occoquan Reservoir.

Relationships to Algae Growth--

Hoehn et al. (21) reported that a good relationship was observed between chlorophyll-a concentrations in the raw water and the TTHM concentrations in FCWA finished water (See Figure 15). Chlorophyll concentrations indicate the density of algae populations within the reservoir but are not as precise as other measures,such as cell numbers, areal standards units of algae, etc. Chlorophyll data were not included in the statistical analysis just completed, but other statistical procedures, which will include the algae-related data, are being evaluated to determine if a model can be developed.

As has been previously mentioned, the finished-water TTHM concentrations during the summer of 1976 were considerably lower than during the summer of 1975. It was also observed that the average raw-water chlorophyll-a concentrations also were lower during the summer of 1976 (12 μg/l) than during a similar period in 1975 (44 μg/l). During the summer of 1976, there was considerably less rainfall, which markedly decreased the runoff contributions of fertilizer nutrients (phosphorus and nitrogen) that encourage algae growth. The decreased runoff also reduced the humate contributions from the surrounding watershed as well, but the relationship between algae and TTHM, as shown by Figure 15, indicates that algae as contributors of THM precursors cannot be ignored. The summer of 1977 was not included in this project period, but the

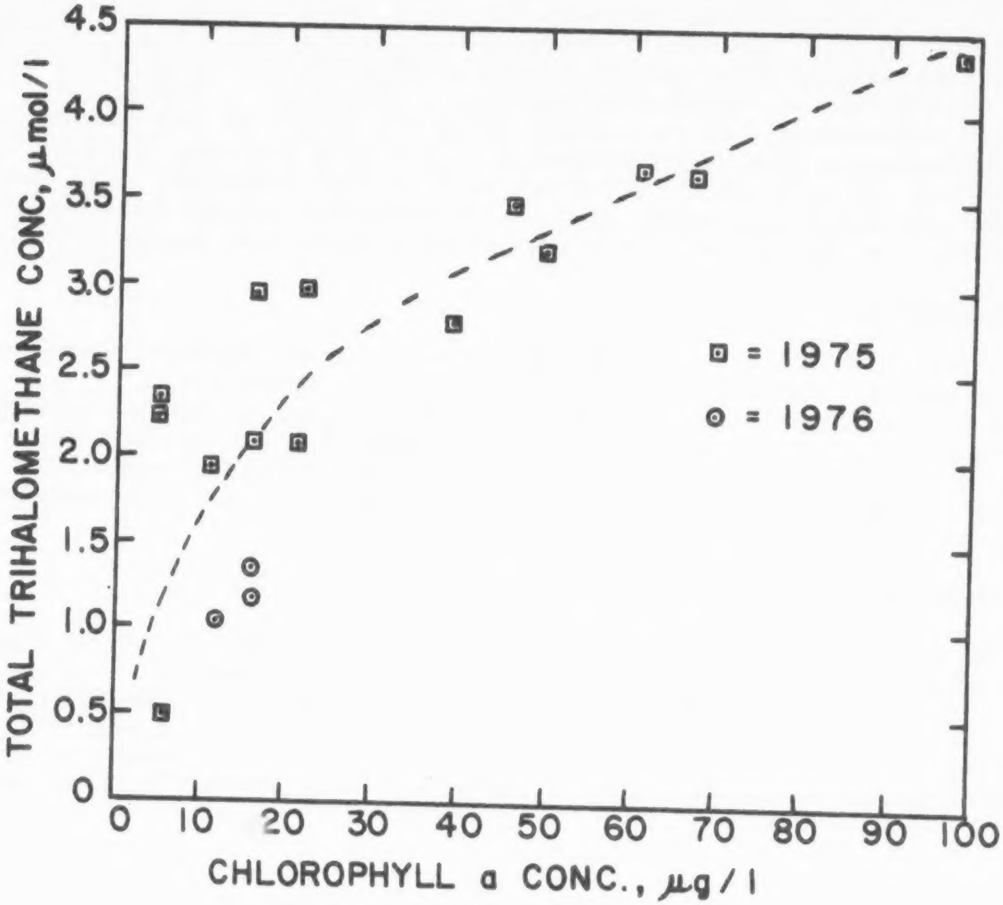

Figure 15. Relationship between concentration of chlorophyll-a concentrations in the Occoquan Reservoir and finished-water TTHM concentrations during the summers of 1975 and 1976. (Only single values were available for June, July, and August, 1976. There was no September measurement).

Occoquan Monitoring Program continued, and the data showed that the algal growth-limited by the absence of adequate phosphorus at the dam. That year was a severe drought year, and the reservoir stage reached its lowest point since the high dam was constructed more than a decade ago. Some data collected independently by the authors during the summer of 1977 showed that the finished-water TTHM concentrations at Site D were less than the proposed MCL of 100 μg/1, which is further evidence that conditions which favor high THM concentrations, namely high humate concentrations and increased algae growth in the raw water, are related to rainfall and, hence, runoff.

Special Studies

In addition to the routine THM monitoring program, two special studies were conducted-- one to determine if any changes in finished-water THM concentration would occur with time of water flow from the tap and the other to determine if significantly greater concentrations of THM's were present in filter back-wash water at the treatment plant than in the finished water passing through the filter. These studies are discussed in the following paragraphs.

THM Concentration Variations with Time of Flow From Tap--

On two occasions (June 8 and 15, 1977) samples at Site G were collected for analysis at small time intervals after the tap was opened. The objective was to determine if the THM concentrations observed at a given location might be affected by the length of time the tap was opened before the sample to be analyzed was collected. Site G was selected for this study because it was the most distant in the distribution system and chlorine concentrations were consistently lower there than at the other sites (See Table 22).

Table 28 summarizes the data obtained during these experiments. Note that there was an increase in THM concentrations in samples collected after the initial sample on both occasions. The extremely low $CHCl_3$ concentration observed on June 8 (1 μg/1) was lower than any ever observed, and it was not an error in the analysis. On June 15, the TTHM concentration in the initial sample was less than one-half that in the next sample. Note that the chlorine concentrations in the first sample collected on both days was zero but reached its maximum rather quickly. The data indicate that some factor may be reducing THM concentrations in the distribution system. This possibility, as well as the factors related to chlorine dissipation, merits further investigation.

Haloforms in Filter Back-Wash Water--

In June, 1977, four samples of back-wash water from the FCWA New Lorton facility were collected and analyzed for volatile organics, TOC, and chlorine. On two occasions, the water passing the filter immediately before and after backwash were also collected for analysis. Table 29 shows the results of these analyses.

It can be seen that the differences in haloform concentrations before, after, and during backwash were all about the same in spite of the fact that the TOC concentrations in the backwash water itself were 2.5 - 3.0 times as

TABLE 28. ANALYTICAL DATA DERIVED FROM EXPERIMENTS TO DETERMINE THE CHANGES IN HALOFORM CONCENTRATIONS AT VARIOUS INTERVALS AFTER OPENING SAMPLING TAP IN DISTRIBUTION SYSTEM OF THE FAIRFAX COUNTY WATER AUTHORITY IN DUMFRIES, VA., (SITE G)[a]

Sampling Date	Time Lapse (min) After Tap Opened[b]	pH	Temp °C	Chlorine Residual mg/l		Haloform Concentrations,[c] µg/l						TOC mg/l
				Total	Free	$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$	$CHBr_3$	CCl_4	$ClCH_2CH_2Cl$	
June 8 (1977)	0 (10:10 am)	7.7	17	0	0	1	12	1	*	*	*	1.77
	2.5	7.6	20	1.0	0.9	NOT ANALYZED						1.90
	5	7.9	21	1.0	1.0	174	20	*	*	*	*	1.60
	10	7.7	21	1.0	0.9	169	18	*	*	*	*	2.13
June 15 (1977)	0 (9:15 am)	7.3	22	0	0	90[d]	14	*	*	*	*	1.15
	1	-	21	1.3	1.0	236	21	*	*	*	*	1.68
	5	-	21	1.4	1.1	241	21	*	*	*	*	1.70

[a] Water had no unusual odor, color, or turbidity

[b] On June 8, tap had not been opened all morning prior to study. On June 15, however, it had been opened several times before the study commenced.

[c] Asterisks indicate concentrations less than 1.0 µg/l. All other values are the maximum concentrations that developed in samples, i.e. they were not dechlorinated when collected.

[d] A second sample collected at 9:15 a.m. was chlorinated with approximately 5 mg/l. After 30 minutes, the chlorine concentrations were 4.0 and 3.2 mg/l, respectively, for total and free residuals. Haloform analyses revealed 872 µg/l and 34 µg/l for $CHCl_3$ and $CHBrCl_2$, respectively. In addition, there was 10 µg/l dichloroethane. All others were <1.0 µg/l.

TABLE 29. ANALYTICAL DATA COLLECTED DURING SPECIAL STUDIES TO DETERMINE TERMINAL HALOFORM CONCENTRATIONS IN FINISHED WATER IMMEDIATELY PRECEDING AND FOLLOWING FILTER BACKWASH AND IN THE BACKWASH WATER ITSELF.

LOCATION: PIPE GALLERY OF NEW LORTON FACILITY, FAIRFAX COUNTY WATER AUTHORITY, JUNE 1977

Sampling Date	Sample Description	pH	Time	Temp °C	Chlorine Residual, mg/l		Physical Condition	TOC, mg/l	[*]Concentration, μg/l		
					Total	Free			$CHCl_3$	$CHBrCl_2$	$CHBr_2Cl$
June 2	Backwash Filter No. 1	7.4	10:20am	20.5	†	†	Turbid, Iron Floc	3.79	136	11	<1
June 3	Backwash Filter No. 2	7.7	9:45am	21.0	†	†	Turbid, Iron Floc	3.72	150	15	1
June 6	Pre-Backwash Filter No. 3	7.6	8:50am	21.0	2.7	2.4	Clear, No Color or Odor	1.52	196	21	1
	Post-Backwash Filter No. 3	7.6	12:05pm	21.0	3.2	2.7	Clear, No Color or Odor	1.60	205	21	1
June 7	Pre-Backwash Filter No. 4	7.6	9:10am	21.0	2.3	2.1	Clear, No Color or Odor	1.45	190	21	1
	Backwash Filter No. 4	7.6	11:45am	21.0	[†]3.0	[†]2.2	Turbid, Iron Floc	5.52	169	15	1
	Post-Backwash Filter No. 4	7.6	12:10pm	21.0	2.3	2.0	Clear, No Color or Odor	1.59	189	21	1
June 10	Backwash Filter No. 4	7.4	9:30am	20.5	[†]2.5	[†]2.1	Turbid, Iron Floc	4.91	117	16	<1

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[*] Concentrations of $CHBr_3$, CCl_4, and DCE were all < 1 μg/l. Samples were not dechlorinated.

[†] Interference with the DPD procedure on June 2 and 3. Samples collected June 7 and 10 were analyzed by amperometric titration.

high as in the other samples. Of course, what is not known is how long the chlorine persisted after the samples were collected, and it is possible that the haloform reaction in the samples of backwash water were chlorine limited. However, the nature of the organics may have been such that they did not readily enter the haloform reaction.

The objective of the study was to determine if the water passing a filter immediately before and after a filter had been disturbed by backwashing would be more likely to contain higher concentrations of TOC and haloforms than at other times. No significant differences were observed.

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SUPPLEMENTAL DATA

The contract required that with each sampling, supplemental data--including pH, chlorine residuals, bacterial counts, weather conditions, and notes concerning any unusual water-quality characteristics-- be collected and compiled. The data appear in Appendix D. Table D-1 includes information related to virus monitoring, another aspect of the contract not covered by this report, but Table D-2 contains supplemental data relative only to the volatile organics sampling program.

APPENDIX A

Heavy Metal Concentrations At Sites A Through F for the Period June, 1975 - May, 1976

TABLE A-1. MONTHLY AND DAILY VARIATIONS IN HEAVY METAL CONCENTRATIONS AT CATHARPIN ON BULL RUN ABOVE TREATED SEWAGE DISCHARGES (SITE A), JUNE, 1975 - MAY, 1976

Date	METAL, µg/1											
	Ag	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Se	Zn
June 4	0	0	60	60	0	10	462	0	53	0	0	32
July 8	0	0	130	12	0	11	370	0	132	0	0	207
August 5	0	0	0	0	20	14	520	0	195	0	0	12
September 9	3	0	0	0	0	15	300	0	23	0	0	7
September 10	0	0	30	0	0	0	290	0	34	0	0	13
September 11	0	0	0	0	0	12	260	0	39	0	0	6
September 12	0	0	20	0	0	31	250	0	30	0	0	6
September 13	0	0	0	0	0	33	240	0	22	0	0	7
September 14	0	0	0	0	0	10	260	0	26	0	0	11
September 15	0	0	0	0	0	18	250	0	33	0	0	5
October 7	0	0	0	0	0	10	310	0	25	0	0	30
November 11	0	0	0	0	0	35	290	0.9	11	0	0	18
December 9	0	0	0	0	0	11	660	0	33	0	0	32
*January 13	0	0	0	1	0	7	590	0	34	0	0	370
January 27	0	0	0	0	0	21	850	0	72	0	0	19
February 18	0	0	0	0	0	0	320	0	16	0	0	15
March 9	0	0	0	2	0	3	420	0	19	0	0	7
April 13	0	0	0	0	0	21	380	0	17	0	0	18
May 11	11	0	20	0	0	20	670	0	28	0	0	6

* Redone January 27 due to contamination.

TABLE A-2. MONTHLY AND DAILY VARIATIONS IN HEAVY METAL CONCENTRATIONS ON BULL RUN BELOW TREATED SEWAGE DISCHARGES (SITE B), JUNE, 1975 - MAY, 1976

Date	METAL, µg/1											
	Ag	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Se	Zn
June 4	0	0	70	0	10	248	686	0	127	5	0	13
July 8	0	0	320	0	20	20	270	0	128	0	0	339
August 5	0	0	40	0	7	26	340	0	76	0	0	17
September 9	0	0	50	0	0	19	380	0	96	0	0	10
September 10	2	0	0	0	0	16	380	0	97	0	0	65
September 11	0	0	0	0	0	18	390	0	88	0	0	20
September 12	0	0	0	0	0	38	410	0	90	0	0	7
September 13	0	0	0	0	0	31	550	0	119	0	0	14
September 14	0	0	20	0	0	12	420	0	54	0	0	16
September 15	0	0	0	0	0	15	360	0	69	0	0	8
October 7	0	0	0	0	0	8	550	0	95	0	0	16
November 11	0	0	0	0	0	17	310	0	50	0	0	49
December 9	0	0	30	0	0	7	980	0	148	0	0	28
January 13	0	0	0	1	0	6	600	0	101	0	0	16
February 18	0	0	0	0	0	11	510	0	99	0	0	25
March 9	0	0	30	0	0	4	600	0	115	0	0	11
April 13	0	0	0	0	0	6	440	0	77	0	0	6
May 11	4	0	0	0	0	6	500	0	131	0	0	7

TABLE A -3. MONTHLY AND DAILY VARIATIONS IN HEAVY METAL CONCENTRATIONS IN THE INTAKE WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT FACILITY (SITE C), JUNE, 1975 - MAY, 1976

Date	METAL, μg/1											
	Ag	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Se	Zn
June 2	0	0	10	2	10	417	272	0	174	15	0	18
July 7	0	0	190	<2	40	235	540	0	362	0	0	158
August 4	0	0	40	0	5	295	2080	0	1034	50	0	25
September 9	0	0	0	0	0	253	880	0	838	0	0	14
September 10	0	0	0	0	0	227	380	0	215	80	0	59
*September 11	0	0	6	0	0	188	646	0	608	16	0	6
September 12	0	0	0	0	0	250	1800	0	1968	0	0	6
September 13	0	0	100	0	0	581	2830	0	3230	10	0	19
September 14	0	0	60	0	0	488	3310	0	3610	35	0	49
September 15	0	0	50	0	0	129	560	0	450	30	0	42
October 6	0	0	0	0	0	127	1160	0	260	0	0	25
November 10	0	0	0	0	0	169	470	0	181	0	0	16
December 8	0	0	30	0	0	46	1250	1.5	220	0	0	29
January 12	0	0	0	0	0	76	810	0	102	0	0	18
February 17	0	0	0	1	0	252	3720	0	861	15	0	25
March 8	0	0	30	0	0	9	460	0	94	0	0	4
April 12	0	0	0	2	0	47	560	0	109	0	0	14
May 10	9	0	0	0	0	50	1410	0	245	0	0	7

* Values are average of bihourly analyses.

TABLE A-4. MONTHLY AND DAILY VARIATIONS IN HEAVY METAL CONCENTRATIONS IN THE FINISHED WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT FACILITY (SITE D), JUNE, 1975 - MAY, 1976

Date	METAL, µg/1											
	Ag	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Se	Zn
June 2	0	0	50	0	0	240	50	0	13	10	0	251
July 7	0	0	110	2	0	44	130	0	3	0	0	250
August 4	0	0	0	0	0	123	150	0	26	40	0	44
September 9	0	0	0	0	0	395	1390	0	21	100	0	314
September 10	0	0	0	0	0	302	670	0	8	25	0	265
*September 11	0	0	8	0	0	80	108	0	1	9	0	32
September 12	0	0	0	0	0	194	600	0	6	20	0	103
September 13	0	0	40	0	0	238	550	0	0	10	0	144
September 14	0	0	0	0	0	300	590	0	0	12	0	163
September 15	0	0	0	0	0	276	520	0	0	10	0	125
October 6	0	0	0	0	0	1404	1320	0	57	80	0	628
November 10	0	0	20	0	0	307	740	0	6	25	0	326
December 8	0	0	50	0	0	251	1140	2.5	31	40	0	214
January 12	0	0	20	1.2	0	258	1110	0	51	8	0	66
February 17	0	0	0	1	0	419	180	0	13	0	0	46
March 8	0	0	20	0	3	317	1160	0	38	0	0	25
April 12	0	0	0	3	0	289	200	0	14	0	0	35
May 10	1	0	0	0	0	40	130	0	18	0	0	30

*Values are average of bihourly analyses.

Note: High concentrations of Cu, Fe, Pb, and Zn are probably accounted for by the fact that samples were the first water out of the tap after standing for long periods.

TABLE A-5. MONTHLY AND DAILY VARIATIONS IN HEAVY METAL CONCENTRATIONS IN THE DISTRIBUTION SYSTEM AT THE FAIRFAX COUNTY WATER AUTHORITY'S STORAGE YARD (SITE E), JUNE, 1975 - MAY, 1976

Date	METAL, μg/1											
	Ag	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Se	Zn
June 3	0	0	10	0	20	459	31	0	7	10	0	65
July 7	0	0	200	0	10	118	0	0	2	0	0	192
August 4	0	0	0	0	0	382	70	0	15	0	0	35
September 9	0	0	0	0	0	525	30	0	0	20	0	20
September 10	0	0	0	0	0	298	20	0	0	0	0	10
*September 11	0	0	20	0	0	35	15	0	0	0	0	4
September 12	0	0	40	0	0	73	30	0	0	0	0	27
September 13	0	0	20	0	0	399	40	0	8	0	0	10
September 14	0	0	10	0	0	647	60	0	0	10	0	23
September 15	0	0	0	0	0	522	30	0	0	10	0	83
October 6	0	0	0	0	0	21	40	0	0	0	0	6
October 8	0	0	0	0	0	50	50	0	0	0	0	17
November 10	0	0	0	0	0	202	60	0	0	10	0	142
December 8	0	0	0	0	0	134	80	0	12	20	0	87
January 12	0	0	0	0	0	1089	30	0	11	10	0	65
February 17	0	0	0	0	0	870	10	0	7	30	0	110
March 8	0	0	0	0	0	334	10	0	2	30	0	24
April 12	0	0	0	4	0	719	50	0	13	5	0	85
May 10	0	0	20	0	0	90	70	0	15	0	0	35

*Values are average of bihourly analyses.

Note: Site E is no longer under the control of FCWA. Operations were discontinued in February,1978.

TABLE A-6. MONTHLY AND DAILY VARIATIONS IN HEAVY METAL CONCENTRATIONS IN THE DISTRIBUTION SYSTEM AT ALEXANDRIA, VIRGINIA (SITE F), JUNE, 1975 - MAY, 1976

Date	METAL, μg/1											
	Ag	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Se	Zn
June 3	0	0	20	0	0	161	55	0	13	0	0	56
July 7	0	0	150	0	0	56	50	0	0	1	0	217
August 4	0	0	20	0	0	46	260	0	17	0	0	13
September 9	0	0	0	0	0	63	50	0	0	0	0	38
September 10	0	0	0	0	0	61	60	0	0	0	0	34
*September 11	0	0	23	0	0	44	58	0	0	0	0	6
September 12	0	0	30	0	0	46	30	0	0	0	0	54
September 13	0	0	0	0	0	50	40	0	0	0	0	21
September 14	0	0	0	0	0	179	60	0	0	0	0	42
September 15	0	0	0	0	0	56	130	0	0	10	0	30
October 6	0	0	0	0	0	22	70	0	0	0	0	17
October 8	0	0	0	0	0	34	130	0	15	0	0	45
November 10	0	0	0	0	0	58	70	0	0	0	0	56
December 8	0	0	0	0	0	24	110	0	16	0	0	26
January 12	0	0	0	3	0	47	80	0	9	5	0	114
February 17	0	0	0	0	0	29	100	0.25	10	0	0	39
March 8	0	0	0	0	0	36	30	0	5	0	0	36
April 12	0	0	0	0	0	71	80	0	14	2	0	54
May 10	0	0	0	0	0	30	160	0	23	0	0	10

*Values are average of bihourly analyses.

TABLE A-7. BIHOURLY VARIATIONS IN HEAVY METAL CONCENTRATIONS IN THE INTAKE WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT FACILITY (SITE C), SEPTEMBER 11, 1975

Time	METAL, μg/1											
	Ag	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Se	Zn
2400	0	0	0	0	0	172	610	0	712	0	0	12
0200	0	0	0	0	0	121	700	0	818	0	0	11
0400	0	0	0	0	0	111	690	0	646	0	0	9
0600	0	0	0	0	0	139	620	0	722	0	0	6
0800	2	0	0	0	0	128	700	0	729	0	0	3
1000	0	0	0	0	0	125	740	0	771	0	0	5
1200	0	0	40	0	0	143	860	0	909	50	0	4
1400	0	0	0	0	0	156	960	0	881	44	0	2
1600	0	0	30	0	0	139	830	0	728	50	0	4
1800	0	0	0	0	0	218	350	0	192	0	0	4
2000	0	0	10	0	0	322	430	0	337	20	0	4
2200	0	0	0	0	0	346	350	0	244	48	0	0
2400	0	0	0	0	1	328	560	0	211	0	0	11
*Mean	0	0	6	0	0	188	646	0	608	16	0	6
Standard Deviation	0.5	0	13.2	-	0.3	86.4	188.4	-	262.5	22.7	-	3.8

*Mean values rounded to nearest whole number.

TABLE A-8. BIHOURLY VARIATIONS IN HEAVY METAL CONCENTRATIONS IN THE FINISHED WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT FACILITY (SITE D), SEPTEMBER 11, 1975

Time	METAL, µg/1											
	Ag	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Se	Zn
2400	0	0	0	0	0	214	370	0	0	20	0	116
0200	0	0	40	0	0	100	110	0	0	0	0	48
0400	0	0	0	0	0	99	100	0	0	15	0	42
0600	0	0	50	0	0	104	100	0	0	10	0	42
0800	0	0	0	0	0	57	30	0	0	25	0	14
1000	0	0	0	0	0	22	50	0	0	23	0	4
1200	0	0	0	0	0	24	80	0	0	25	0	6
1400	0	0	0	0	0	72	100	0	0	0	0	19
1600	0	0	0	0	0	62	80	0	0	0	0	21
1800	0	0	0	0	0	62	80	0	5	0	0	22
2000	0	0	0	0	0	65	70	0	6	0	0	21
2200	0	0	0	0	0	86	110	0	0	0	0	30
2400	0	0	20	0	0	76	120	0	5	0	0	27
*Mean	0	0	8	0	0	80	108	0	1	9	0	32
Standard Deviation	-	-	17.2	-	-	47.7	82.8	-	2.4	10.9	-	28.6

*Mean values rounded to nearest whole number.

TABLE A-9. BIHOURLY VARIATIONS IN HEAVY METAL CONCENTRATIONS IN THE DISTRIBUTION SYSTEM AT THE FAIRFAX COUNTY WATER AUTHORITY'S STORAGE YARD (SITE E), SEPTEMBER 11, 1975

Time	METAL, µg/1											
	Ag	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Se	Zn
2400	0	0	0	0	0	48	15	0	0	0	0	8
0200	0	0	80	0	0	46	16	0	0	0	0	6
0400	0	0	0	0	0	48	18	0	0	0	0	5
0600	0	0	40	0	0	32	16	0	0	0	0	5
0800	0	0	40	0	0	30	30	0	0	0	0	8
1000	0	0	30	0	0	37	40	0	0	0	0	10
1200	0	0	0	0	0	31	40	0	0	0	0	11
1400	0	0	0	0	0	32	0	0	0	0	0	0
1600	0	0	40	0	0	34	0	0	0	0	0	4
1800	0	0	0	0	0	30	0	0	0	0	0	0
2000	0	0	30	0	0	27	0	0	0	0	0	0
2200	0	0	0	0	0	25	0	0	0	0	0	0
2400	0	0	0	0	0	31	20	0	0	0	0	0
*Mean	0	0	20	0	0	35	15	0	0	0	0	4
Standard Deviation	-	-	25.5	-	-	7.8	14.8	-	-	-	-	4.1

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*Mean values rounded to nearest whole number.

TABLE A-10. BIHOURLY VARIATIONS IN HEAVY METAL CONCENTRATIONS IN THE DISTRIBUTION SYSTEM AT ALEXANDRIA, VIRGINIA (SITE F), SEPTEMBER 11, 1975

Time	METAL, µg/1											
	Ag	As	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Se	Zn
2400	0	0	0	0	0	30	30	0	2	0	0	17
0200	0	0	20	0	0	34	30	0	0	0	0	6
0400	0	0	20	0	0	33	50	0	0	0	0	14
0600	0	0	0	0	0	44	10	0	0	0	0	13
0800	0	0	70	0	0	51	60	0	0	0	0	0
1000	0	0	80	0	0	61	60	0	0	0	0	6
1200	0	0	80	0	0	47	80	0	0	0	0	0
1400	0	0	0	0	0	53	100	0	0	0	0	0
1600	0	0	30	0	0	48	90	0	0	0	0	6
1800	0	0	0	0	0	47	60	0	0	0	0	4
2000	0	0	0	0	0	42	70	0	0	0	0	2
2200	0	0	0	0	0	35	70	0	0	0	0	4
2400	0	0	0	0	0	41	50	0	0	0	0	6
*Mean	0	0	23	0	0	44	58	0	0	0	0	6
Standard Deviation	-	-	32.2	-	-	9.0	25.1	-	0.6	-	-	5.5

*Mean values rounded to nearest whole number.

APPENDIX B

Pesticide Concentrations at Sites A Through F for the Period June - November, 1975

TABLE B-1. CONCENTRATION OF ORGANOCHLORINE PESTICIDES OBSERVED AT CATHARPIN ON BULL RUN UPSTREAM OF TREATED SEWAGE DISCHARGES (SITE A), JUNE, 1975 - MAY, 1976 (No data indicates none found)

Date	PESTICIDE, µg/1									
	Aldrin[a]	Chlor-dane[c]	DDT*[b]	Dieldrin[a]	Endrin[b]	Hepta-Chlor[a]	H. Epoxide[a]	Lindane[a]	Methoxy-Chlor[b]	Toxa-Phene[d]
June 4	-	-	-	T	-	T	T	0.020	0,08	-
June 10	-	-	T	-	-	-	-	T	-	-
June 17	-	-	-	T	-	T	T	0.010	T	-
June 24	-	-	1.00	-	-	T	T	T	2.00	-
July 1	-	T	-	T	-	T	T	0.010	T	-
July 8	T	-	0.04	-	-	-	T	T	T	-
July 15	T	-	0.50	-	0.40	-	-	0.006	T	-
July 22	-	-	-	-	-	-	-	T	-	-
July 29	-	-	T	-	-	-	-	T	0.10	-
Aug. 5	T	-	0.30	T	T	-	-	T	-	-
Aug. 12	-	-	-	-	T	-	T	-	-	-
Aug. 19	-	0.387	1.29	-	T	-	-	0.038	-	-
Aug. 26	-	-	T	T	T	T	T	-	T	-
Sept. 2	-	0.370	T	-	-	-	-	-	T	-
Sept. 9	-	-	T	-	-	-	0.017	T	T	-
Sept. 10	T	-	T	T	-	-	0.005	T	-	-
Sept. 11	-	T	T	-	-	T	T	T	T	-
Sept. 12	0.009	-	-	T	T	-	0.010	T	0.030	-
Sept. 13	-	-	T	T	0.008	-	T	0.004	-	-
Sept. 14	-	T	0.017	T	0.005	T	0.007	0.010	-	-
Sept. 15	T	-	T	-	-	T	0.002	T	-	-
Sept. 16	-	-	0.011	0.003	-	T	0.003	T	-	-
Sept. 23	-	-	0.013	T	T	T	0.007	-	T	-
Sept. 30	T	-	T	T	-	T	0.012	T	T	-
Oct. 7	-	-	0.004	-	-	-	-	-	-	-
Nov. 11	-	-	0.002	-	-	-	-	-	-	-
+Dec. 9	-	-	0.020	-	-	-	T	-	-	-
Jan. 13	-	-	0.004	-	T	T	T	T	-	-
Feb. 18	-	-	0.050	-	-	-	-	T	-	-
March 9	-	-	T	-	T	0.001	0.001	0.002	-	-
April 13	-	-	T	0.002	T	T	T	T	-	-
May 11	-	-	T	0.002	0.001	T	0.002	T	-	-

* pp isomer

[a] T = <0.001 µg/1

[b] T = <0.002 µg/1

[c] T = <0.005 µg/1

[d] T = <0.01 µg/1

+ Confirmed by mass spectroscopy

TABLE B-2. CONCENTRATIONS OF ORGANOCHLORINE PESTICIDES OBSERVED ON BULL RUN DOWNSTREAM OF TREATED SEWAGE DISCHARGES (SITE B), JUNE, 1975 - MAY, 1976 (No data indicates none found)

Date	PESTICIDE, μg/l									
	Aldrin[a]	Chlor-dane[c]	DDT*[b]	Dieldrin[a]	Endrin[b]	Hepta-Chlor[a]	H. Epoxide[a]	Lindane[a]	Methoxy-Chlor[b]	Toxa-Phene[d]
June 4	-	-	0.008	T	0.006	T	T	0.020	-	-
June 10	T	-	-	-	-	-	-	-	-	-
June 17	-	-	-	-	-	-	T	0.006	-	-
June 24	T	-	T	-	-	-	-	T	-	-
July 1	-	-	0.030	-	-	-	-	0.010	T	-
July 8	T	-	0.070	0.010	-	-	T	T	T	-
July 15	T	-	T	-	-	-	T	T	T	-
July 22	T	-	2.00	0.02	-	-	T	0.020	0.60	-
July 29	T	-	T	0.02	T	-	-	0.010	0.20	-
Aug. 5	T	-	0.020	-	-	- -	T	0.080	-	-
Aug. 12	-	-	-	-	-	-	-	T	-	0.237
Aug. 19	T	-	0.382	-	-	T	T	0.007	-	0.500
Aug. 26	-	-	0.014	0.009	-	-	T	-	T	-
Sept. 2	T	-	0.044	0.013	T	-	0.025	0.037	-	-
Sept. 9	T	T	T	0.007	-	-	0.007	0.007	-	-
+Sept. 10	T	-	T	0.003	-	-	0.003	T	-	-
Sept. 11	-	-	T	0.006	-	T	0.005	T	-	T
Sept. 12	-	-	0.005	0.005	T	T	0.003	T	0.015	-
Sept. 13	-	-	T	0.002	-	T	0.003	T	-	-
Sept. 14	T	-	0.005	T	-	T	T	T	T	-
Sept. 15	T	T	T	0.003	T	-	-	0.003	-	-
Sept. 16	-	-	0.012	0.002	-	T	0.002	T	T	-
Sept. 23	-	-	0.012	0.001	-	T	0.002	T	T	-
+Sept. 30	-	T	T	-	-	T	0.028	T	T	-
Oct. 7	T	-	T	-	-	T	0.010	T	-	-
Nov. 11	-	-	-	-	-	-	-	-	-	-
Dec. 9	-	-	0.031	T	-	T	T	T	-	-
Jan. 13	0.015	-	T	T	-	T	T	-	0.085	-
Feb. 18	-	-	0.075	-	-	-	-	T	-	-
March 9	-	-	0.009	-	-	0.001	0.002	T	-	-
April 13	-	-	T	T	-	T	0.0009	T	-	-
May 11	-	-	0.004	0.002	0.002	T	0.003	T	-	-

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[*] pp isomer

[a] T = <0.001 μg/l

[b] T = <0.002 μg/l

[c] T = <0.005 μg/l

[d] T = <0.01 μg/l

+ Confirmed by mass spectroscopy

TABLE B-3. CONCENTRATIONS OF ORGANOCHLORINE PESTICIDES OBSERVED IN THE RAW WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT PLANT (SITE C), JUNE, 1975 - MAY, 1976 (No data indicates none found)

Date	PESTICIDE, μg/l									
	Aldrin[a]	Chlordane[c]	DDT*[b]	Dieldrin[a]	Endrin[b]	Hepta-Chlor[a]	H. Epoxide[a]	Lindane[a]	Methoxy-Chlor[b]	Toxa-Phene[d]
June 2	-	T	-	T	T	-	-	T	-	-
June 9	-	-	T	-	-	T	T	T	-	-
June 16	-	-	T	-	-	-	-	T	-	-
June 23	-	-	1.00	-	-	T	T	T	T	-
June 30	-	-	-	-	-	-	-	T	T	-
July 7	-	-	2.00	4.000	-	-	-	-	2.00	-
July 14	-	-	3.00	-	T	-	-	T	-	-
July 21	-	-	0.01	-	-	-	-	T	-	-
July 28	-	-	T	0.005	T	-	T	0.060	0.30	-
August 4	-	-	T	T	T	-	T	-	-	-
August 11	-	-	T	-	T	-	-	-	-	-
August 18	-	-	T	T	T	-	T	T	-	-
August 25	-	-	T	T	T	-	0.013	0.020	-	-
Sept. 1	-	T	-	T	T	-	T	T	-	-
+Sept. 9	0.015	-	0.036	T	-	T	0.018	T	T	-
Sept. 10	0.003	-	0.007	0.003	-	T	0.004	T	-	-
**Sept. 11	0.001	0	0.230	0.081	0.011	0	0.001	0.058	0.003	0
Sept. 12	-	-	T	T	-	-	-	-	T	-
Sept. 13	T	-	T	T	-	T	T	T	0.06	-
Sept. 14	T	-	-	T	-	T	T	T	-	-
Sept. 15	T	-	T	T	-	T	T	0.003	-	-
Sept. 16	-	-	T	0.001	-	T	0.002	T	T	-
Sept. 22	-	-	0.009	T	-	T	0.003	T	-	-
+Sept. 29	T	-	T	-	-	T	0.020	T	-	-
Oct. 6	-	-	0.002	-	-	-	0.001	0.001	-	-
Nov. 10	-	-	0.002	0.001	-	-	-	-	-	-
Dec. 8	-	-	T	T	-	T	T	T	-	-
Jan. 12	-	-	-	-	-	T	T	-	-	-
+Feb. 17	0.004	-	0.01	-	-	T	T	T	0.013	-
March 8	-	-	T	-	T	0.001	0.002	T	-	-
April 12	-	-	T	0.001	-	T	0.002	T	-	-
May 10	-	-	T	0.006	-	-	T	-	-	-

* pp isomer

[a] T = <0.001 μg/l

[b] T = <0.002 μg/l

[c] T = <0.005 μg/l

[d] T = <0.01 μg/l

+ Confirmed by mass spectroscopy

**Values are average of bihourly analyses. Trace values considered 0 when calculating mean.

TABLE B-4. CONCENTRATIONS OF ORGANOCHLORINE PESTICIDES OBSERVED IN FINISHED WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT PLANT (SITE D), JUNE, 1975 - MAY, 1976 (No data indicates none found)

Date	PESTICIDE, µg/1									
	Aldrin[a]	Chlor-dane[c]	DDT*[b]	Dieldrin[a]	Endrin[b]	Hepta-Chlor[a]	H. Epoxide[a]	Lindane[a]	Methoxy-Chlor[b]	Toxa-Phene[d]
June 2	-	-	T	-	-	-	-	T	-	-
June 9	-	-	T	-	-	T	T	T	0.07	-
June 16	-	-	-	T	-	-	T	T	0.10	-
June 23	-	-	.080	-	-	-	-	T	-	-
June 30	-	-	-	-	-	-	-	T	-	-
July 7	T	-	.090	-	T	T	T	T	0.04	-
July 14	-	-	T	-	-	-	-	T	-	-
July 21	T	-	.030	-	-	-	-	T	-	-
July 28	T	-	-	T	-	-	-	T	0.50	-
August 4	-	-	T	-	-	-	T	T	-	-
August 11	-	-	T	T	T	-	T	T	-	-
August 18	-	-	T	-	-	-	-	T	-	-
August 25	-	-	T	T	T	-	-	-	-	-
Sept. 1	-	-	-	T	T	T	T	T	-	-
Sept. 9	0.004	-	0.011	T	-	-	T	-	-	-
Sept. 10	T	-	T	-	-	T	T	-	-	-
**Sept. 11	0	0	0.002	0	0	0	0	0	0.015	0
Sept. 12	-	T	T	T	-	-	T	-	T	-
Sept. 13	-	-	-	T	-	-	-	T	-	-
Sept. 14	-	-	-	T	-	T	T	T	-	-
Sept. 15	0.02	-	T	-	T	T	T	0.004	0.040	-
Sept. 16	-	-	T	-	-	-	T	T	T	-
Sept. 22	T	-	0.021	T	-	T	T	T	-	T
Sept. 29	T	-	T	-	-	T	0.010	T	T	-
Oct. 6	T	T	T	-	-	T	0.022	T	T	-
Nov. 10	-	-	0.001	-	-	-	-	-	-	-
Dec. 8	-	-	0.004	-	-	-	T	T	-	-
+Jan. 12	-	-	0.199	-	-	-	-	-	-	-
Feb. 17	T	-	T	T	T	-	-	T	0.052	-
March 8	T	-	T	-	T	0.001	0.002	T	-	-
April 12	-	-	T	T	T	T	0.0009	T	-	-
May 10	-	-	T	-	-	-	T	T	-	-

* pp isomer

[a] T = <0.001 µg/1

[b] T = <0.002 µg/1

[c] T = <0.005 µg/1

[d] T = <0.01 µg/1

**Values are average of bihourly analyses. Trace values considered 0 when calculating mean.

+ Confirmed by mass spectroscopy

TABLE B-5. CONCENTRATIONS OF ORGANOCHLORINE PESTICIDES OBSERVED IN THE DISTRIBUTION SYSTEM AT THE FAIRFAX COUNTY WATER AUTHORITY'S STORAGE YARD (SITE E), JUNE, 1975 - MAY, 1976 (No data indicates none found)

Date	PESTICIDE, µg/1									
	Aldrin[a]	Chlor-dane[c]	DDT*[b]	Dieldrin[a]	Endrin[b]	Hepta-Chlor[a]	H. Epoxide[a]	Lindane[a]	Methoxy-Chlor[b]	Toxa-Phene[d]
June 3	-	-	T	-	T	-	-	-	-	-
June 11	-	-	T	-	-	T	T	T	-	-
June 18	-	-	T	-	-	T	T	T	-	-
June 23	-	-	T	-	-	-	-	T	-	-
June 30	-	-	T	-	-	-	-	T	-	-
July 7	T	-	0.080	T	-	-	-	T	T	-
July 14	-	-	T	-	-	T	-	T	-	-
July 21	-	-	0.008	-	-	-	-	T	-	-
July 28	T	-	-	-	-	-	T	T	-	-
August 4	-	-	T	T	T	-	T	-	-	-
August 11	-	T	T	T	T	T	T	T	-	-
August 18	-	-	T	-	-	-	-	T	T	-
August 25	-	-	-	T	-	T	T	T	-	-
Sept. 1	-	0.041	T	-	T	-	-	T	-	-
Sept. 9	-	-	0.006	-	-	-	T	-	T	-
Sept. 10	-	-	0.007	-	-	T	T	T	-	-
**Sept. 11	0	0	0.001	0	0	0	0.004	0	0.001	0
Sept. 12	-	-	T	-	-	T	T	-	-	-
Sept. 13	T	T	T	T	-	-	-	T	0.060	-
Sept. 14	-	-	T	-	-	T	T	T	T	-
Sept. 15	T	-	-	T	T	T	T	0.004	-	-
Sept. 16	T	-	T	-	-	T	T	T	-	-
Sept. 22	-	-	T	-	-	T	T	-	-	-
Sept. 29	T	-	T	-	-	T	0.014	T	-	-
Oct. 6	T	-	T	-	-	T	0.011	T	-	-
Nov. 10	-	-	-	-	-	-	-	-	-	-
Dec. 8	-	-	0.060	-	-	-	T	-	-	-
Jan. 12	-	-	T	-	-	-	-	T	0.070	-
+Feb. 17	0.004	-	0.188	-	-	-	-	0.004	0.008	-
March 8	-	-	T	-	T	0.004	0.004	T	0.001	-
April 12	T	-	T	0.002	T	0.001	0.002	T	-	-
May 10	-	-	T	-	-	T	T	T	-	-

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* pp isomer

[a] T = <0.001 µg/l

[b] T = <0.002 µg/1

[c] T = <0.005 µg/1

[d] T = <0.01 µg/1

+ Confirmed by mass spectroscopy

**Values are average of bihourly analyses. Trace values considered 0 when calculating mean.

TABLE B -6. CONCENTRATIONS OF ORGANOCHLORINE PESTICIDES OBSERVED IN THE DISTRIBUTION SYSTEM AT ALEXANDRIA, VIRGINIA (SITE F), JUNE, 1975 - MAY, 1976 (No data indicates none found)

Date	PESTICIDE, µg/1									
	Aldrin[a]	Chlor-dane[c]	DDT*[b]	Dieldrin[a]	Endrin[b]	Hepta-Chlor[a]	H. Epoxide[a]	Lindane[a]	Methoxy-Chlor[b]	Toxa-Phene[d]
June 3	-	-	T	-	-	-	-	T	0.060	-
June 11	-	-	-	-	-	T	T	T	-	-
June 18	-	-	T	-	-	T	T	T	T	-
June 23	-	-	T	-	-	-	-	T	-	-
June 30	0.030	-	-	-	-	-	-	T	-	-
July 7	-	-	0.230	-	-	-	-	-	0.020	-
July 14	-	-	0.009	-	-	-	-	-	-	-
July 21	-	-	T	-	-	T	-	0.009	-	-
July 28	T	-	T	-	-	T	-	-	-	-
August 4	-	-	T	T	-	-	-	-	-	-
August 11	T	-	T	T	T	T	T	T	-	-
August 18	-	-	T	T	T	-	T	0.009	-	-
August 25	-	-	T	T	T	T	T	T	T	-
Sept. 1	T	-	T	T	T	-	-	T	-	-
+Sept. 9	T	-	0.038	-	-	T	T	T	-	-
Sept. 10	-	-	-	-	-	-	T	-	-	-
**Sept. 11	0	0	0	0	0	0	0	0	0	0
Sept. 12	-	-	T	-	-	-	T	-	-	-
Sept. 13	T	-	T	T	T	T	T	T	-	-
Sept. 14	T	T	T	T	T	T	T	T	-	-
Sept. 15	-	-	-	T	-	T	T	-	0.040	-
Sept. 16	-	-	T	T	-	T	T	T	-	-
Sept. 22	-	-	0.015	-	-	T	T	-	-	-
Sept. 29	T	-	T	-	-	T	0.010	T	-	-
Oct. 6	T	-	T	-	-	T	0.10	T	T	-
Nov. 10	-	-	0.001	-	-	-	-	-	-	-
Dec. 8	-	-	T	-	T	-	-	-	0.128	-
Jan. 12	-	-	0.090	-	-	-	-	T	-	-
Feb. 17	-	-	0.128	-	-	-	-	-	-	-
March 8	-	T	T	-	T	T	T	T	-	-
April 12	-	T	T	T	-	T	T	T	-	-
May 10	-	T	T	T	-	T	T	T	-	-

* pp isomer

[a] T = <0.001 µg/l

[b] T = <0.002 µg/1

[c] T = <0.005 µg/1

[d] T = <0.01 µg/1

+ Confirmed by mass spectroscopy

**Values are average of bihourly analyses. Trace values considered 0 when calculating mean.

TABLE B -7. BIHOURLY VARIATIONS IN ORGANOCHLORINE PESTICIDE CONCENTRATIONS IN THE RAW WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT PLANT (SITE C), SEPTEMBER 11, 1975

Time	PESTICIDE, µg/1									
	Aldrin[a]	Chlor-dane[c]	DDT*[b]	Dieldrin[a]	Endrin[b]	Hepta-chlor[a]	H. Epoxide[a]	Lindane[a]	Methoxy-chlor[b]	Toxa-phene[d]
2400	-	-	0.770	-	-	-	-	-	-	-
0200	-	-	0.845	0.370	-	-	-	0.355	-	-
0400	-	-	1.365	0.345	-	-	-	-	-	-
0600	-	-	-	0.325	0.145	-	-	0.395	-	-
0800	0.002	-	T	0.002	T	-	0.002	T	0.009	-
1000	0.003	-	T	0.002	-	T	0.002	T	0.021	-
1200	T	-	T	T	T	T	0.003	T	0.008	-
1400	T	T	T	0.003	T	T	T	T	-	-
1600	0.002	-	T	0.002	T	T	0.003	T	-	-
1800	0.002	-	0.006	0.002	-	T	0.002	T	T	-
2000	0.003	-	T	0.003	-	-	0.003	T	-	-
2200	T	-	T	0.002	-	T	0.003	T	-	-
2400	-	-	T	T	T	-	T	T	-	-

* pp isomer

[a] T = <0.001 µg/1

[b] T = <0.002 µg/1

[c] T = <0.005 µg/1

[d] T = <0.01 µg/1

TABLE B-8. BIHOURLY VARIATIONS IN ORGANOCHLORINE PESTICIDE CONCENTRATIONS IN FINISHED WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT PLANT (SITE D), SEPTEMBER 11, 1975

Time	PESTICIDE, µg/1									
	Aldrin[a]	Chlordane[c]	DDT*[b]	Dieldrin[a]	Endrin[b]	Heptachlor[a]	H. Epoxide[a]	Lindane[a]	Methoxychlor[b]	Toxaphene[d]
2400	T	-	T	T	-	-	-	T	0.01	-
0200	T	T	T	T	-	-	-	T	-	-
0400	T	T	T	T	-	T	T	T	0.05	-
0600	-	T	-	T	-	T	T	T	T	-
0800	-	-	T	T	-	-	-	T	0.04	-
1000	-	-	T	-	-	-	-	-	0.02	-
1200	-	-	T	T	-	-	-	T	0.04	-
1400	-	-	T	-	-	-	-	-	0.03	-
1600	-	-	0.010	-	-	-	T	-	-	-
1800	-	-	T	-	-	-	T	-	T	-
2000	-	-	0.008	T	-	T	T	-	-	-
2200	-	-	0.007	-	-	-	T	-	-	-
2400	-	-	0.008	-	-	-	T	-	-	-

* pp isomer

[a] T = <0.001 µg/1

[b] T = <0.002 µg/1

[c] T = <0.005 µg/1

[d] T = <0.01 µg/1

TABLE B-9. BIHOURLY VARIATIONS IN ORGANOCHLORINE PESTICIDE CONCENTRATIONS IN THE DISTRIBUTION SYSTEM AT THE FAIRFAX COUNTY WATER AUTHORITY'S STORAGE YARD (SITE E), SEPTEMBER 11, 1975

Time	PESTICIDE, µg/1									
	Aldrin[a]	Chlordane[c]	DDT*[b]	Dieldrin[a]	Endrin[b]	Heptachlor[a]	H. Epoxide[a]	Lindane[a]	Methoxychlor[b]	Toxaphene[d]
2400	-	-	T	-	-	-	T	-	-	-
0200	T	-	T	-	-	T	T	T	T	-
0400	T	-	0.007	-	-	-	T	-	-	-
0600	T	-	T	-	T	T	T	-	-	-
0800	T	-	T	-	-	T	T	T	-	-
1000	T	T	T	-	-	T	0.012	T	-	-
1200	T	T	-	-	-	T	0.03	T	-	-
1400	T	T	T	-	-	T	0.010	T	-	-
1600	-	T	-	-	T	-	-	-	-	-
1800	T	-	T	-	-	T	T	-	-	-
2000	-	-	T	-	-	-	T	-	-	-
2200	-	-	T	-	-	-	T	-	-	-
2400	T	-	0.010	-	T	T	T	-	0.016	-

* pp isomer

[a] T = <0.001 µg/1

[b] T = <0.002 µg/1

[c] T = <0.005 µg/1

[d] T = <0.01 µg/1

TABLE B-10. BIHOURLY VARIATIONS IN ORGANOCHLORINE PESTICIDE CONCENTRATIONS IN THE DISTRIBUTION SYSTEM AT ALEXANDRIA, VIRGINIA (SITE F), SEPTEMBER 11, 1975

Time	PESTICIDE, µg/1									
	Aldrin[a]	Chlordane[c]	DDT*[b]	Dieldrin[a]	Endrin[b]	Heptachlor[a]	H. Epoxide[a]	Lindane[a]	Methoxychlor[b]	Toxaphene[d]
2400	-	-	T	-	-	-	T	-	-	-
0200	-	-	T	T	-	-	T	-	-	-
0400	T	-	T	-	-	T	T	-	-	-
0600	T	-	-	-	-	-	T	-	T	-
0800	-	-	T	-	-	-	T	-	-	-
1000	-	-	T	-	-	-	T	-	-	-
1200	-	-	T	T	-	T	T	T	-	-
1400	-	-	T	-	-	T	T	T	-	-
1600	-	-	T	-	-	T	T	T	-	-
1800	T	-	T	-	-	T	T	T	-	-
2000	-	-	T	-	-	-	T	-	-	-
2200	-	-	T	-	-	-	T	T	T	-
2400	-	-	T	-	-	-	T	-	-	-

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* pp isomer

[a] T = <0.001 µg/1

[b] T = <0.002 µg/1

[c] T = <0.005 µg/1

[d] T = <0.01 µg/1

TABLE B-11. CONCENTRATIONS OF THREE HERBICIDES OBSERVED AT CATHARPIN ON BULL RUN UPSTREAM OF TREATED SEWAGE DISCHARGES (SITE A), JUNE - NOVEMBER, 1975
(No data indicates none found)

Date	HERBICIDE, μg/1		
	2, 4 - D	2, 4, 5, - TP	2, 4, 5 - T*
June 4	0.600	0.100	-
June 17	0.400	0.020	-
July 1	0.300	0.100	Trace
July 15	0.060	Trace	Trace
July 29	-	Trace	-
August 12	-	0.012	Trace
August 26	0.106	0.014	Trace
September 9	-	0.004	Trace
September 23	0.022	0.002	-
October 7	-	0.006	-
November 11	0.006	0.003	Trace

Trace = <0.001 μg/1

* Not required by contract.

TABLE B-12. CONCENTRATIONS OF THREE HERBICIDES OBSERVED ON BULL RUN DOWNSTREAM OF TREATED SEWAGE DISCHARGES (SITE B), JUNE - NOVEMBER, 1975
(No data indicates none found)

Date	HERBICIDE, μg/1		
	2, 4 - D	2, 4, 5 - TP	2, 4, 5 - T*
June 4	0.500	Trace	Trace
June 17	2.000	0.200	-
July 1	0.300	0.100	Trace
July 15	0.222	Trace	-
July 29	Trace	-	-
August 12	Trace	0.011	-
August 26	-	0.012	-
September 9	-	0.004	Trace
September 23	0.012	0.001	0.005
October 7	-	0.008	-
November 11	0.007	0.001	Trace

Trace = <0.001 μg/1

* Not required by contract.

TABLE B-13. CONCENTRATIONS OF THREE HERBICIDES OBSERVED IN THE RAW WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT PLANT (SITE C), JUNE - NOVEMBER, 1975
(No data indicates none found)

Date	HERBICIDE, µg/1		
	2, 4 - D	2, 4, 5 - TP	2, 4, 5 - T*
June 2	Trace	-	Trace
June 16	0.500	0.020	-
June 30	0.200	0.100	Trace
July 14	0.079	-	Trace
July 28	Trace	Trace	-
August 11	Trace	0.012	Trace
August 25	Trace	0.014	Trace
September 9	Trace	0.005	0.014
September 22	0.030	0.013	0.018
October 6	-	0.003	0.012
November 10	0.009	0.002	Trace

Trace = <0.001 µg/1

* Not required by contract.

TABLE B-14. CONCENTRATIONS OF THREE HERBICIDES OBSERVED IN THE FINISHED WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT PLANT (SITE D),
JUNE - NOVEMBER, 1975
(No data indicates none found)

Date	HERBICIDE, μg/1		
	2, 4, - D	2, 4, 5 - TP	2, 4, 5 - T*
June 2	0.400	0.800	-
June 16	0.400	0.020	Trace
June 30	0.400	0.300	Trace
July 14	0.132	Trace	-
July 28	Trace	Trace	-
August 11	Trace	0.014	Trace
August 25	-	0.012	-
September 9	Trace	0.003	Trace
September 22	0.015	0.001	0.008
October 6	-	0.008	Trace
November 10	0.006	0.001	0.007

Trace = <0.001 μg/1

* Not required by contract.

APPENDIX C

Volatile Organics Concentrations at Sites A-F, Occoquan-I and Sites C-G, Occoquan-II

TABLE C-1. CONCENTRATIONS (MICROGRAMS PER LITER) OF CHLOROFORM MEASURED WEEKLY— JUNE AND JULY, 1975— AT SIX SAMPLING SITES WITHIN THE OCCOQUAN WATERSHED AND WATER SERVICE AREA

Site	Weeks of June, 1975					Weeks of July, 1975			
	1	2	3	4	5	1	2	3	4
A	7	1	3	2	-	<1	<1	<1	1
B	5	3	12	4	3	20	<1	<1	<1
C	26	9	3	4	18	2	12	<1	3
D	156	198	220	223 (230)+	181	310	342	370	321 (339)++
E	57	193 (193)+	243 (212)+	227	204	259	296	379	326
F	154	131	-	214	209	332	234	400	361

Site A: Catharpin on Bull Run above major sewage treatment plant discharges
Site B: Bull Run below major sewage treatment plant discharges
Site C: Intake, Fairfax County Water Authority's Water treatment facility (FCWA)
Site D: Finished water; FCWA water treatment facility
Site E: Distribution System, FCWA's storage yard
Site F: Distribution System; Alexandria, Virginia

+ Duplicate analysis results in parentheses confirmed by mass spectroscopy

++ Duplicate analysis results in parentheses

TABLE C-2. CONCENTRATIONS (MICROGRAMS PER LITER) OF CHLOROFORM MEASURED WEEKLY AUGUST-SEPTEMBER, 1975 AT SIX SAMPLING SITES WITHIN THE OCCOQUAN WATERSHED AND WATER SERVICE AREA

Site	Weeks of August, 1975				Weeks of September, 1975				
	1	2	3	4	1	2	3*	4	5
A	<1	<1	1	3	1	3	2	-	-
B	2	2	2	2	<1	3	2	-	-
C	<1	2	1	<1	<1	2	<1	-	1
D	297	312	258	221	285	262	220	155	168
E	328	378	459	291	326	380	271	170	124
F	325	297	373	320	244	402	259	190	196

Site A: Catharpin on Bull Run above major sewage treatment plant discharges
Site B: Bull Run below major sewage treatment plant discharges
Site C: Intake, Fairfax County Water Authority's Water treatment facility (FCWA)
Site D: Finished water; FCWA water treatment facility
Site E: Distribution System, FCWA's storage yard
Site F: Distribution System; Alexandria, Virginia

* Average of daily analyses, September 10-16 (September 11 values = average of bihourly analyses)

Values <1 considered 0 when calculating mean.

TABLE C -3. DAILY VARIATIONS IN CONCENTRATIONS (MICROGRAMS PER LITER) OF CHLOROFORM AT SIX SAMPLING SITES WITHIN THE OCCOQUAN WATERSHED AND WATER SERVICE AREA, SEPTEMBER 9-16, 1975

SITE	September Date								Mean**	Standard Deviation
	9	10	11	12	13	14	15	16		
A	3	2	1	<1	<1	-	7(7)+	-	2.2	2.6
B	3	2	1	2	2	2	-	-	2.0	0.6
C	2	<1	1*	1	<1	<1	<1	1	<1	0.7
D	262	360	386*	23(22)+	245	222	93	210	225	122
E	380	414	394*	146	268	295	164	217	285	104
F	402	433	348*	171	55	-	307	242	280	134

Site A: Catharpin on Bull Run above major sewage treatment plant discharges
Site B: Bull Run below major sewage treatment plant discharges
Site C: Intake, Fairfax County Water Authority's water treatment facility (FCWA)
Site D: Finished water; FCWA Water Treatment facility
Site E: Distribution System, FCWA's storage yard
Site F: Distribution System, Alexandria, Virginia

* Mean bihourly values

** Values <1 considered 0 when calculating mean

+ Duplicate analysis results in parentheses

TABLE C -4. CONCENTRATIONS (MICROGRAMS PER LITER) OF CHLOROFORM MEASURED MONTHLY— OCTOBER, 1975 - MAY, 1976— AT SIX SAMPLING SITES WITHIN THE OCCOQUAN WATERSHED AND WATER SERVICE AREA

SITE	Month							
	October	November	December	January	February	March	April	May
A	3(3)[+]	2	3	5	<1	1	11	-
B	3	1	6	3	<1	<1	7	-
C	3	<1	8	2	<1	2	7	2
D	-	149	119	50	139	150	112	120
E	319(287)[+]	132	105	36	113	140	102	107
F	354(317)[+]	142	110	37	110	135	113	131

Site A: Catharpin on Bull Run above major sewage treatment plant discharges
Site B: Bull Run below major sewage treatment plant discharges
Site C: Intake, Fairfax County Water Authority's Water treatment facility (FCWA)
Site D: Finished water; FCWA water treatment facility
Site E: Distribution System, FCWA's storage yard
Site F: Distribution System; Alexandria, Virginia

[+] Duplicate analyses in parentheses

TABLE C-5. BIHOURLY VARIATIONS IN THE CONCENTRATIONS (MICROGRAMS PER LITER) OF HALOGENATED METHANES OBSERVED IN RAW WATER (SITE C) AND FINISHED WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT PLANT (SITE D), SEPTEMBER 11, 1975

Site C*		Site D		
Time	$CHCl_3$	Time	$CHCl_3$	$CHCl_2Br$
2400	3	2400	418	26
0210	2	0200	445	19
0410	<1	0400	345	17
0610	<1	0600	337	29
0810	<1	0810	390	19
1010	<1	1000	398	19
1200	-	1200	376	21
1410	<1	1400	392	21
1610	2	1600	378	22
1805	3	1800	384	17
2000	5	2000**	378	24
2215	<1	2200	413	23
2400	<1	2400	367	21
Mean***	1.3	Mean***	386.2	21.4
Standard Deviation	1.7	Standard Deviation	29.0	3.5
Range	0-5	Range	337-445	17-29

* Dichlorobromomethane ($CHBrCl_2$) concentration all <1

** 1 μg/l dibromochloromethane, $CHClBr_2$, was found also at this time at Site D.

*** Values <1 considered 0 when calculating mean

TABLE C-6. BIHOURLY VARIATIONS IN THE CONCENTRATIONS OF HALOGENATED METHANES (MICROGRAMS PER LITER) OBSERVED IN TWO DISTRIBUTION SYSTEM SITES: FAIRFAX COUNTY WATER AUTHORITY'S STORAGE YARD (SITE E) AND IN ALEXANDRIA, VIRGINIA (SITE F) ON SEPTEMBER 11, 1975

Time	SITE E		SITE F		
	$CHCl_3$	$CHCl_2Br$	$CHCl_3$	$CHCl_2Br$	$CHClBr_2$
2400	363	22	256	16	<1
0200	447	25	404	22	2
0400	419	23	391	23	1
0600	400	24	404	20	2
0800	379	23	423	23	1
1000	382	22	373	18	10
1200	404	25	345	14	6
1400	352	27	413	21	6
1600*	379	22	236	14	6
1800	398	23	314	17	2
2000	410	22	342	18	3
2200	405	23	332	19	<1
2400	390	20	298	20	6
Mean**	394.5	23.2	348.5	18.9	3.5
Standard Deviation	24.7	1.8	60.3	3.1	3.0
Range	352-447	20-27	236-423	14-23	0-10

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* At Site F, 1 μg/l bromoform, $CHBr_3$, was found also at this time.

** Values <1 considered 0 when calculating mean

TABLE C-7. CONCENTRATIONS ≥ 1 µg/l DIBROMOCHLOROMETHANE AND 1, 2-DICHLOROETHANE + CARBON TETRACHLORIDE* OBSERVED AT VARIOUS SITES WITHIN THE OCCOQUAN WATERSHED AND WATER SERVICE AREA, JUNE 1975-MAY 1976

COMPOUND	SITE	DATE OBSERVED	CONCENTRATION, µg/l
$CHClBr_2$	D	August 25	1
		September 1	1
		September 11	1
		November 10	2
	E	August 18	1
		October 8	2
	F	June 30	1
		July 7	1
		August 4	5
		August 18	1
		August 25	1
		September 1	1
		September 11	(See Table C-6)
		October 6	2
		October 8	3
		November 10	6
1, 2-DCE* + CCl_4	A	June 17	10
		June 24	4
		September 11	1
		October 7	2
	B	June 10	4
		June 24	3
		July 1	3
		September 11	1
		October 7	4
	C	June 9	1
		June 16	1
		June 28	1
	D	June 9	34

* Separation not attained

TABLE C-8. CONCENTRATIONS (MICROGRAMS PER LITER) OF DICHLOROBROMOMETHANE MEASURED WEEKLY--JUNE-JULY, 1975-- AT SIX SITES WITHIN THE OCCOQUAN WATERSHED AND WATER SERVICE AREA

Site	Weeks of June, 1975					Weeks of July, 1975			
	1	2	3	4	5	1	2	3	4
A	<1	<1	0	0	-	<1	<1	<1	<1
B	<1	<1	1	3	<1	<1	<1	<1	<1
C	<1	<1	<1	0	2	<1	<1	<1	<1
D	4	11	17	17(20)$^{+}$	20	17	30	34	18(21)$^{++}$
E	1	20(22)$^{+}$	20(21)$^{+}$	23	26	18	32	30	28
F	3	10	-	24	25	20	18	16	37

Site A:	Catharpin on Bull Run above major sewage treatment plant discharges
Site B:	Bull Run below major sewage treatment plant discharges
Site C:	Intake, Fairfax County Water Authority's Water treatment facility (FCWA)
Site D:	Finished water; FCWA water treatment facility
Site E:	Distribution System, FCWA's storage yard
Site F:	Distribution System; Alexandria, Virginia

$^{+}$ Duplicate analysis results in parentheses confirmed by mass spectroscopy

$^{++}$ Duplicate analysis results in parentheses

TABLE C-9. CONCENTRATIONS (MICROGRAMS PER LITER) OF DICHLOROBROMOMETHANE MEASURED WEEKLY-AUGUST-SEPTEMBER, 1975- AT SIX SITES WITHIN THE OCCOQUAN WATERSHED AND WATER SERVICE AREA

Site	Weeks of August, 1975				Weeks of September, 1975				
	1	2	3	4	1	2	3*	4	5
A	<1	<1	<1	<1	<1	<1	<1	-	-
B	<1	<1	<1	<1	<1	<1	<1	-	-
C	<1	<1	<1	<1	<1	<1	<1	-	<1
D	13	28	26	24	22	28	18	15	17
E	16	28	35	25	26	32	22	16	7
F	25	23	25	22	24	32	20	18	7

Site A:	Catharpin on Bull Run above major sewage treatment plant discharges
Site B:	Bull Run below major sewage treatment plant discharges
Site C:	Intake, Fairfax County Water Authority's water treatment facility (FCWA)
Site D:	Finished water; FCWA water treatment facility
Site E:	Distribution System, FCWA's storage yard
Site F:	Distribution System, Alexandria, Virginia

* Average of daily analyses, September 10-16 (September 11 values = average of bihourly analyses)

Values <1 considered 0 when calculating mean

TABLE C-10. DAILY VARIATIONS IN CONCENTRATIONS (MICROGRAMS PER LITER) OF DICHLOROBROMOMETHANE OBSERVED AT SIX SAMPLING SITES WITHIN THE OCCOQUAN WATERSHED AND WATER SERVICE AREA, SEPTEMBER 9-16, 1975

SITE	September Date								Mean**	Standard Deviation
	9	10	11	12	13	14	15	16		
A	<1	<1	0	<1	<1	-	<1	-	0	-
B	<1	<1	0	<1	<1	<1	-	-	0	-
C	<1	<1	0*	<1	<1	<1	<1	<1	0	-
D	28	29	21*	2	16	16	18	24	19.3	8.6
E	32	26	23*	16	18	20	21	29	23.1	5.5
F	32	26	19*	17	5	-	28	28	22.1	9.7

Site A:	Catharpin on Bull Run above major sewage treatment plant discharges
Site B:	Bull Run below major sewage treatment plant discharges
Site C:	Intake, Fairfax County Water Authority's water treatment facility (FCWA)
Site D:	Finished water; FCWA Water Treatment facility
Site E:	Distribution System, FCWA;s storage yard
Site F:	Distribution System, Alexandria, Virginia

* Mean bihourly values

** Values <1 considered 0 when calculating mean

TABLE C-11. CONCENTRATIONS (MICROGRAMS PER LITER) OF DICHLOROBROMOMETHANE MEASURED MONTHLY-- OCTOBER, 1975 - MAY, 1976-- AT SIX SITES WITHIN THE OCCOQUAN WATERSHED AND WATER SERVICE AREA

SITE	October	November	December	January	February	March	April	May
A	<1	<1	<1	<1	<1	<1	<1	-
B	<1	<1	<1	<1	<1	<1	<1	-
C	<1	<1	<1	<1	1	<1	<1	<1
D	-	17	10	5	14	18	5	14
E	11,17	10	10	4	32	25	8	19
F	10,14	20	11	4	27	27	10	18

Site A: Catharpin on Bull Run above major sewage treatment plant discharges
Site B: Bull Run below major sewage treatment plant discharges
Site C: Intake, Fairfax County Water Authority's Water treatment facility (FCWA)
Site D: Finished water; FCWA water treatment facility
Site E: Distribution System, FCWA's storage yard
Site F: Distribution System; Alexandria, Virginia

TABLE C-12. CONCENTRATIONS OF HALOFORMS AND TOTAL ORGANIC CARBON OBSERVED IN RAW WATER AT THE FAIRFAX COUNTY WATER AUTHORITY WATER TREATMENT PLANT (SITE C) DURING THE PERIOD FROM JUNE, 1976 THROUGH MAY, 1977.

(Asterisks indicate concentrations less than 1.0 µg/1.)

Sampling Date	Sampling Time		$CHCl_3$ µg/1	$CHBrCl_2$ µg/1	$CHBr_2Cl$ µg/1	$CHBr_3$ µg/1	CCl_4 µg/1	$ClCH_2CH_2Cl$ µg/1	TOC mg/1
June 24	11:25am	[a](1)	2	*	*	*	*	*	4.4
		[b](2)	(sample bottle broken)						
June 30	2:15pm	[a](1)	*	*	*	*	*	*	-
July 20	2:45pm	[a](1)	*	*	*	*	*	*	4.2
		[b](2)	*	*	*	*	*	*	
Aug. 9	9:35am	[a](1)	*	*	*	*	*	*	3.4
Aug. 10	11:10am	[a](1)	3	2	*	*	*	*	3.5
Aug. 11	12:30pm	[a](1)	*	*	*	*	*	*	6.3
Aug. 12	1:05am	[a](1)	*	*	*	*	*	*	3.7
Aug. 13	9:15am	[a](1)	*	*	*	*	*	*	4.4
Sept. 21	9:30am	[a](1)	*	*	*	*	*	*	2.4
Oct. 18	11:10am	[a](1)	*	*	*	*	*	*	5.5
Nov. 8	10:10am	[a](1)	*	*	*	*	*	*	11.5
Dec. 8	3:30pm	[a](1)	*	*	*	*	*	*	4.3
Jan. 11	10:33am	[a](1)	8	*	*	*	*	*	3.5
Feb. 8	10:45am	[a](1)	*	*	*	*	*	1	4.8

(continued)

TABLE C-12 (continued)

Sampling Date	Sampling Time		$CHCl_3$ µg/l	$CHBrCl_2$ µg/l	$CHBr_2Cl$ µg/l	$CHBr_3$ µg/l	CCl_4 µg/l	$ClCH_2CH_2Cl$ µg/l	TOC mg/l
March 7	9:55am	[a](1)	*	*	*	*	*	*	3.7
March 8	10:00am	[a](1)	*	*	*	*	*	*	4.5
March 9	9:55am	[a](1)	*	*	*	*	*	*	2.5
March 10	9:50am	[a](1)	*	*	*	*	*	*	3.0
March 11	10:25am	[a](1)	*	*	*	*	*	*	2.7
April 12	12:15pm	[a](1)	*	*	*	*	*	*	3.1
May 10	12:35pm	[a](1)	*	*	*	*	*	*	3.2

[a] Reaction allowed to go to completion. No dechlorinating agent added.

[b] Sample dechlorinated at time of collection with potassium ferrocyanide.

TABLE C-13. CONCENTRATIONS OF HALOFORMS AND TOTAL ORGANIC CARBON OBSERVED IN FINISHED WATER AT THE FAIRFAX COUNTY WATER AUTHORITY'S WATER TREATMENT PLANT (SITE D) DURING THE PERIOD FROM JUNE, 1976 THROUGH MAY, 1977.
(Asterisks indicate concentrations less than 1.0 μg/1.)

Sampling Date	Sampling Time		$CHCl_3$ μg/1	$CHBrCl_2$ μg/1	$CHBr_2Cl$ μg/1	$CHBr_3$ μg/1	CCl_4 μg/1	$ClCH_2CH_2Cl$ μg/1	TOC mg/1
June 24	12:50pm	[a](1)	112	17	*	*	*	*	4.3
		[b](2)	83	15	*	*	*	*	
		[c](3)	74.1%	88.2%	-	-	-	-	-
June 30	12:50pm	[d](2)	63	10	*	*	*	*	-
	1:05pm	[d](2)	60	10	*	*	*	*	-
July 20	3:20pm	[a](1)	115	26	*	*	*	*	4.0
		[b](2)	97	20	*	*	*	*	
		[c](3)	84.3%	76.9%	-	-	-	-	
August 9	8:35am	[a](1)	858	30	1	*	*	*	38.0
		[b](2)	219	22	*	*	*	*	
		[c](3)	25.5%	73.3%	-	-	-	-	
August 10	9:35am	[a](1)	149	24	1	*	*	*	2.2
		[b](2)	93	16	1	*	*	*	
		[c](3)	62.4%	66.7%	100%	-	-	-	
August 11	1:10pm	[a](1)	127	24	1	*	*	*	1.7
		[b](2)	99	17	1	*	*	*	
		[c](3)	77.9%	70.8%	100%	-	-	-	
August 12	1:40pm	[a](1)	170	27	1	*	*	*	2.5
		[b](2)	115	20	1	*	*	*	
		[c](3)	67.6%	74.1%	100%	-	-	-	
August 13	10:15am	[a](1)	194	35	1	*	*	*	4.0
		[b](2)	118	32	1	*	*	*	
		[c](3)	60.8%	91.4%	100%	-	-	-	

(continued)

TABLE C-13 (continued)

Sampling Date	Sampling Time		$CHCl_3$ µg/1	$CHBrCl_2$ µg/1	$CHBr_2Cl$ µg/1	$CHBr_3$ µg/1	CCl_4 µg/1	$ClCH_2CH_2Cl$ µg/1	TOC mg/1
Sept. 21	10:00am	[a](1)	135	27	2	*	*	*	1.0
		[b](2)	98	23	2	*	*	*	
		[c](3)	72.6%	85.2%	100%	-	-	-	
Oct. 18	12:10pm	[a](1)	261	23	*	*	*	*	2.0
		[b](2)	169	9	*	*	*	*	
		[c](3)	64.8%	39.1%	-	-	-	-	
Nov. 8	10:40am	[a](1)	240	25	*	*	*	*	4.5
		[b](2)	164	17	*	*	*	*	
		[c](3)	68.3%	68.0%	-	-	-	-	
Dec. 18	12:20pm	[a](1)	191	25	*	*	*	*	2.0
		[b](2)	116	13	*	*	*	*	
		[c](3)	60.7%	52.0%	-	-	-	-	
Jan. 11	11:40pm	[a](1)	149	20	*	*	*	*	1.1
		[b](2)	71	25	*	*	*	*	
		[c](3)	47.6%	[e]>100%	-	-	-	-	
Feb. 8	11:10am	[a](1)	202	18	*	*	*	1	1.0
		[b](2)	81	10	*	*	*	1	
		[c](3)	40.1%	55.6%	-	-	-	100%	
March 7	9:10am	[a](1)	40	3	*	*	*	*	1.6
		[b](2)	58	3	*	3	2	*	
		[c](3)	[e]>100%	100%	-	[e]>100%	[e]>100%	-	
March 8	11:30am	[a](1)	109	15	1	1	*	*	2.0
		[b](2)	20	6	*	*	*	*	
		[c](3)	18.4%	40.0%	-	-	-	-	

(continued)

TABLE C-13 (continued)

Sampling Date	Sampling Time		$CHCl_3$ µg/1	$CHBrCl_2$ µg/1	$CHBr_2Cl$ µg/1	$CHBr_3$ µg/1	CCl_4 µg/1	$ClCH_2CH_2Cl$ µg/1	TOC mg/1
March 9	10:50am	^{a}(1)	96	14	*	*	*	*	2.0
		^{b}(2)	33	6	*	*	*	*	-
		^{c}(3)	34.4%	42.9%	-	-	-	-	-
March 10	10:15am	^{a}(1)	98	3	1	*	*	*	2.0
		^{b}(2)	39	2	*	*	1	*	-
		^{c}(3)	39.8%	66.7%	-	-	^{e}>100%	-	-
March 11	11:00am	^{a}(1)	136	17	2	*	*	*	1.0
		^{b}(2)	47	8	*	*	2	*	-
		^{c}(3)	34.6%	47.1%	-	-	^{e}>100%	-	-
April 12	10:30am	^{a}(1)	64	10	*	*	*	*	1.1
		^{b}(2)	32	9	*	*	*	*	-
		^{c}(3)	50.0%	90.0%	-	-	-	-	-
May 10	11:05am	^{a}(1)	121	10	1	*	5	*	1.5
		^{b}(2)	62	8	1	*	5	*	-
		^{c}(3)	51.2%	80.0%	100%	-	100%	-	-

[a] Reaction allowed to go to completion. No dechlorinating agent added.

[b] Sample dechlorinated at time of collection with potassium ferrocyanide.

[c] (2) expressed as a percentage of (1).

[d] Sample dechlorinated with sodium thiosulfate.

[e] Values greater than those observed in samples not dechlorinated are within the range of analytical error.

TABLE C-14. CONCENTRATIONS OF HALOFORMS AND TOTAL ORGANIC CARBON OBSERVED IN FINISHED WATER OF THE FAIRFAX COUNTY WATER AUTHORITY IN THE DISTRIBUTION SYSTEM AT THE AUTHORITY'S STORAGE YARD IN FAIRFAX COUNTY(SITE E) DURING THE PERIOD FROM JUNE, 1976 THROUGH MAY, 1977.
(Asterisks indicate concentrations less than 1.0 µg/1.)

Sampling Date	Sampling Time		$CHCl_3$ µg/1	$CHBrCl_2$ µg/1	$CHBr_2Cl$ µg/1	$CHBr_3$ µg/1	CCl_4 µg/1	$ClCH_2CH_2Cl$ µg/1	TOC mg/1
June 24	2:35pm	^{a}(1)	112	17	*	*	*	*	1.5
		^{b}(2)	93	17	*	*	*	*	-
		^{c}(3)	83.0%	100%	-	-	-	-	-
July 20	10:20am	^{a}(1)	124	23	*	*	*	*	5.7
		^{b}(2)	106	21	*	*	*	*	-
		^{c}(3)	85.5%	91.3%	-	-	-	-	-
Aug. 9	11:50pm	^{a}(1)	192	26	2	*	*	*	2.2
		^{b}(2)	169	24	1	*	*	*	-
		^{c}(3)	88.0%	92.3%	50.0%	-	-	-	-
Aug. 10	12:00pm	^{a}(1)	141	22	1	*	*	*	2.5
		^{b}(2)	120	19	1	*	*	*	-
		^{c}(3)	85.1%	86.4%	100%	-	-	-	-
Aug. 11	9:10am	^{a}(1)	157	26	1	*	*	*	3.8
		^{b}(2)	142	25	1	*	*	*	-
		^{c}(3)	90.4%	96.2%	100%	-	-	-	-
Aug. 12	8:55am	^{a}(1)	195	30	1	*	*	*	2.0
		^{b}(2)	151	25	1	*	*	*	-
		^{c}(3)	77.4%	83.3%	100%	-	-	-	-
Aug. 13	11:30am	^{a}(1)	215	35	1	*	*	*	2.0
		^{b}(2)	153	29	1	*	*	*	-
		^{c}(3)	71.2%	82.9%	100%	-	-	-	-

(continued)

TABLE C-14 (continued)

Sampling Date	Sampling Time		$CHCl_3$ μg/l	$CHBrCl_2$ μg/l	$CHBr_2Cl$ μg/l	$CHBr_3$ μg/l	CCl_4 μg/l	$ClCH_2CH_2Cl$ μg/l	TOC mg/l
Sept. 21	2:20pm	[a](1)	80	22	2	*	*	*	1.0
		[b](2)	74	21	3	*	*	*	-
		[c](3)	92.5%	95.4%	[d]>100%	-	-	-	-
Oct. 18	9:00am	[a](1)	265	20	*	*	*	*	1.7
		[b](2)	191	11	*	*	*	*	-
		[c](3)	72.1%	55.0%	-	-	-	-	-
Nov. 8	2:15pm	[a](1)	224	27	*	*	*	*	5.6
		[b](2)	189	22	*	*	*	*	-
		[c](3)	84.4%	81.5%	-	-	-	-	-
Dec. 13	3:00pm	[a](1)	142	24	*	*	*	*	1.7
		[b](2)	85	16	*	*	*	*	-
		[c](3)	59.9%	66.7%	-	-	-	-	-
Jan. 11	3:12pm	[a](1)	136	24	*	*	*	*	1.2
		[b](2)	62	19	*	*	*	*	-
		[c](3)	45.6%	79.2%	-	-	-	-	-
Feb. 8	3:00pm	[a](1)	196	45	*	*	*	8	2.0
		[b](2)	89	11	*	*	*	2	-
		[c](3)	45.4%	24.4%	-	-	-	25%	-
March 7	2:45pm	[a](1)	126	6	2	*	1	*	6.2
		[b](2)	36	3	*	*	*	*	-
		[c](3)	28.6%	50.0%	-	-	-	-	-
March 8	2:15pm	[a](1)	104	12	2	*	*	*	1.8
		[b](2)	43	2	1	*	1	*	-
		[c](3)	41.4%	16.7%	50%	-	[d]>100%	-	-

(continued)

TABLE C-14 (continued)

Sampling Date	Sampling Time		$CHCl_3$ µg/l	$CHBrCl_2$ µg/l	$CHBr_2Cl$ µg/l	$CHBr_3$ µg/l	CCl_4 µg/l	$ClCH_2CH_2Cl$ µg/l	TOC mg/l
March 9	1:45pm	[a](1)	88	12	*	*	*	*	2.3
		[b](2)	43	8	*	*	*	*	-
		[c](3)	48.9%	66.7%	-	-	-	-	-
March 10	2:50pm	[a](1)	82	4	1	*	*	*	2.3
		[b](2)	24	1	*	*	*	*	-
		[c](3)	29.3%	25.0%	-	-	-	-	-
March 11	7:50am	[a](1)	88	15	2	*	*	*	1.8
		[b](2)	46	9	1	*	1	*	-
		[c](3)	52.3%	60.0%	50.0%	-	[d]>100%	-	-
April 12	9:30am	[a](1)	70	9	*	*	1	*	1.4
		[b](2)	45	7	*	*	3	*	-
		[c](3)	64.3%	77.8%	-	-	[d]>100%	-	-
May 10	10:10am	[a](1)	139	11	1	*	7	*	1.2
		[b](2)	72	8	*	*	5	*	-
		[c](3)	51.8%	72.7%	-	-	71.4%	-	-

[a] Reaction allowed to go to completion. No dechlorinating agent added.

[b] Sample dechlorinated at time of collection with potassium ferrocyanide.

[c] (2) expressed as a percentage of (1).

[d] Values greater than those observed in samples not dechlorinated are within the range of analytical error.

TABLE C-15. CONCENTRATIONS OF HALOFORMS AND TOTAL ORGANIC CARBON IN FINISHED WATER OF THE FAIRFAX COUNTY WATER AUTHORITY IN THE DISTRIBUTION SYSTEM IN ALEXANDRIA, VIRGINIA (SITE F) DURING THE PERIOD FROM JUNE, 1976 THROUGH MAY, 1977. (Asterisks indicate concentrations less than 1.0 μg/1.)

Sampling Date	Sampling Time		$CHCl_3$ μg/1	$CHBrCl_2$ μg/1	$CHBr_2Cl$ μg/1	$CHBr_3$ μg/1	CCl_4 μg/1	$ClCH_2CH_2Cl$ μg/1	TOC mg/1
June 24	3:45pm	^{a}(1)	106	19	*	*	*	*	1.5
		^{b}(2)	95	17	*	*	*	*	
		^{c}(3)	89.6%	89.5%	-	-	-	-	
July 20	1:40pm	^{a}(1)	96	21	*	*	*	*	1.5
		^{b}(2)	83	19	*	*	*	*	
		^{c}(3)	86.5%	90.5%	-	-	-	-	
August 9	1:00pm	^{a}(1)	163	24	1	*	*	*	3.8
		^{b}(2)	138	20	1	*	*	*	
		^{c}(3)	84.7%	83.3%	100%	-	-	-	
August 10	1:04pm	^{a}(1)	146	24	1	*	*	*	3.5
		^{b}(2)	109	17	1	*	*	*	
		^{c}(3)	74.7%	70.8%	100%	-	-	-	
August 11	10:55am	^{a}(1)	148	26	1	*	*	*	1.8
		^{b}(2)	141	23	1	*	*	*	
		^{c}(3)	95.3%	88.5%	100%	-	-	-	
August 12	10:10am	^{a}(1)	176	27	1	*	*	*	1.0
		^{b}(2)	118	20	1	*	*	*	
		^{c}(30	67.0%	74.1%	100%	-	-	-	
August 13	12:40pm	^{a}(1)	200	33	1	*	*	*	2.0
		^{b}(2)	126	24	1	*	*	*	
		^{c}(3)	63.0%	72.7%	100%	-	-	-	

(continued)

TABLE C-15(continued)

Sampling Date	Sampling Time		$CHCl_3$ µg/l	$CHBrCl_2$ µg/l	$CHBr_2Cl$ µg/l	$CHBr_3$ µg/l	CCl_4 µg/l	$ClCH_2CH_2Cl$ µg/l	TOC mg/l
Sept. 21	8:30am	[a](1)	136	28	4	*	*	*	6.2
		[b](2)	124	28	*	*	*	*	
		[c](3)	91.2%	100%	–	–	–	–	
Oct. 18	10:17am	[a](1)	249	22	*	*	*	*	3.0
		[b](2)	178	13	*	*	*	*	
		[c](3)	71.5%	59.1%	–	–	–	–	
Nov. 8	11:35am	[a](1)	204	26	*	*	*	*	5.0
		[b](2)	179	21	*	*	*	*	
		[c](3)	87.8%	80.8%	–	–	–	–	
Dec. 14	3:55pm	[a](1)	142	22	*	*	*	*	2.2
		[b](2)	99	16	*	*	*	*	
		[c](3)	69.7%	72.7%	–	–	–	–	
Jan. 11	12:30pm	[a](1)	164	40	*	*	*	*	1.3
		[b](2)	73	14	*	*	*	*	
		[c](3)	44.5%	35.0%	–	–	–	–	
Feb. 8	12:15pm	[a](1)	194	50	*	*	*	9	1.0
		[b](2)	90	12	*	*	*	2	
		[c](3)	46.4%	24.0%	–	–	–	22.2%	
March 7	11:45am	[a](1)	96	12	*	*	*	*	2.3
		[b](2)	47	10	1	*	*	*	
		[c](3)	49.0%	83.3	[d]>100%	–	–	–	

(continued)

TABLE C-15 (continued)

Sampling Date	Sampling Time		$CHCl_3$ µg/l	$CHBrCl_2$ µg/l	$CHBr_2Cl$ µg/l	$CHBr_3$ µg/l	CCl_4 µg/l	$ClCH_2CH_2Cl$ µg/l	TOC mg/l
March 8	2:10pm	[a](1)	51	11	*	*	*	*	1.6
		[b](2)	19	7	*	*	*	*	
		[c](3)	37.2%	63.6%	-	-	-	-	
March 9	11:45am	[a](1)	95	14	*	*	*	*	2.0
		[b](2)	47	8	*	*	*	*	
		[c](3)	49.5%	57.1%	-	-	-	-	
March 10	1:30pm	[a](1)	73	4	1	*	*	*	2.3
		[b](2)	41	2	*	*	*	*	
		[c](3)	56.2%	50.0%	-	-	-	-	
March 11	12:05pm	[a](1)	114	14	1	*	*	*	1.8
		[b](2)	54	9	2	*	1	*	
		[c](3)	47.4%	64.3%	[d]>100%	*	[d]>100%		
April 12	8:30am	[a](1)	66	9	*	*	*	*	1.4
		[b](2)	38	3	*	*	*	*	-
		[c](3)	57.6%	33.3%	-	-	-	-	-
May 10	9:15am	[a](1)	115	11	2	*	5	*	1.4
		[b](2)	83	9	1	*	5	*	-
		[c](3)	72.2%	81.8%	50%	-	100%	-	-

[a] Reaction allowed to go to completion. No dechlorinating agent added.

[b] Sample dechlorinated at time of collection with potassium ferrocyanide.

[c] (2) expressed as a percentage of (1).

[d] Values greater than those observed in samples not dechlorinated are within the range of analytical error.

TABLE C-16. CONCENTRATIONS OF HALOFORMS AND TOTAL ORGANIC CARBON IN FINISHED WATER OF THE FAIRFAX COUNTY WATER AUTHORITY IN THE DISTRIBUTION SYSTEM IN DUMFRIES, VIRGINIA, (SITE G) DURING THE PERIOD FROM JUNE, 1976 THROUGH MAY, 1977. (Asterisks indicate concentrations less than 1.0 μg/1)

Sampling Date	Sampling Time		$CHCl_3$ μg/1	$CHBrCl_2$ μg/1	$CHBr_2Cl$ μg/1	$CHBr_3$ μg/1	CCl_4 μg/1	$ClCH_2CH_2Cl$ μg/1	TOC mg/1
June 24	5:15pm	^{a}(1)	129	21	*	*	*	*	2.3
		^{b}(2)	137	21	*	*	*	*	
		^{c}(3)	>100%	100%	-	-	-	-	
July 20	4:05pm	^{a}(1)	115	24	1	*	*	*	3.3
		^{b}(2)	152	23	1	*	*	*	
		^{c}(3)	>100%	95.8%	100%	-	-	-	
Aug. 9	2:55pm	^{a}(1)	182	24	1	*	*	*	1.4
		^{b}(2)	196	23	1	*	*	*	
		^{c}(3)	>100%	95.8%	100%	-	-	-	
Aug. 10	3:15pm	^{a}(1)	190	27	1	*	*	*	3.2
		^{b}(2)	178	26	1	*	*	*	
		^{c}(3)	93.7	96.3%	100%	-	-	-	
Aug. 11	2:45pm	^{a}(1)	204	30	1	*	*	*	3.3
		^{b}(2)	175	27	1	*	*	*	
		^{c}(3)	85.8%	90.0%	100%	-	-	-	
Aug. 12	12:15pm	^{a}(1)	172	26	1	*	*	*	1.0
		^{b}(2)	162	24	1	*	*	*	
		^{c}(3)	94.2%	92.3%	100%	-	-	-	
Aug. 13	2:05pm	^{a}(1)	215	34	2	*	*	*	1.5
		^{b}(2)	171	25	2	*	*	*	
		^{c}(3)	79.5%	73.5%	100%	-	-	-	

(continued)

TABLE C-16 (continued)

Sampling Date	Sampling Time		$CHCl_3$ µg/1	$CHBrCl_2$ µg/1	$CHBr_2Cl$ µg/1	$CHBr_3$ µg/1	CCl_4 µg/1	$ClCH_2CH_2Cl$ µg/1	TOC mg/1
Sept. 21	11:18am	^{a}(1)	105	26	3	*	*	*	7.0
		^{b}(2)	110	26	4	*	*	*	
		^{c}(3)	71.0%	100%	^{d}>100%	-	-	-	
Oct. 18	1:15pm	^{a}(1)	306	23	*	*	*	*	2.2
		^{b}(2)	310	20	*	*	*	*	
		^{c}(3)	>100%	87.0%	-	-	-	-	
Nov. 8	9:20am	^{a}(1)	186	16	*	*	*	*	3.5
		^{b}(2)	170	12	*	*	*	*	
		^{c}(3)	91.4%	75.0%	-	-	-	-	
Dec. 14	2:25pm	^{a}(1)	221	27	*	*	*	*	2.0
		^{b}(2)	155	17	*	*	*	*	
		^{c}(3)	70.1%	63.0%	-	-	-	-	
Jan. 11	9:30am	^{a}(1)	197	38	*	*	*	*	1.1
		^{b}(2)	163	28	*	*	*	*	
		^{c}(3)	82.7%	73.7%	-	-	-	-	
Feb. 8	9:57am	^{a}(1)	110	17	*	*	*	6	1.0
		^{b}(2)	117	14	*	*	*	1	
		^{c}(3)	>100%	82.4%	-	-	-	16.7%	
March 7	10:40am	^{a}(1)	133	15	2	*	2	*	2.3
		^{b}(2)	34	8	*	*	*	*	
		^{c}(3)	25.6%	53.3%	-	-	-	-	
March 8	9:20am	^{a}(1)	54	9	*	*	*	*	1.8
		^{b}(2)	28	5	*	*	*	*	
		^{c}(3)	52%	56%	-	-	-	-	

(continued)

TABLE C-16 (continued)

Sampling Date	Sampling Time		$CHCl_3$ µg/l	$CHBrCl_2$ µg/l	$CHBr_2Cl$ µg/l	$CHBr_3$ µg/l	CCl_4 µg/l	$ClCH_2CH_2Cl$ µg/l	TOC mg/l
March 9	9:20am	[a](1)	97	3	*	*	1	*	2.7
		[b](2)	52	9	*	*	3	*	-
		[c](3)	53.6%	>100%	-	-	[d]>100%	-	-
March 10	9:20am	[a](1)	80	3	*	*	*	*	1.3
		[b](2)	48	2	*	*	1	*	-
		[c](3)	60.0%	66.7%	-	-	[d]>100%	1	-
March 11	9:35am	[a](1)	104	12	1	*	*	*	3.5
		[b](2)	41	7	*	*	*	*	-
		[c](3)	39.4%	58.3%	-	-	-	-	-
April 12	1:05	[a](1)	105	12	*	*	5	*	1.6
		[b](2)	90	12	*	*	6	*	-
		[c](3)	85.7%	100%	-	-	[d]>100%	-	-
May 10	1:15	[a](1)	172	12	*	*	6	*	1.5
		[b](2)	138	9	*	*	5	*	-
		[c](3)	80.2%	75.0%	-	-	83.3%	-	-

[a] Reaction allowed to go to completion. No dechlorinating agent added.

[b] Sample dechlorinated at time of collection with potassium ferrocyanide.

[c] (2) expressed as a percentage of (1).

[d] Values greater than those observed in samples not dechlorinated are within the range of analytical error.

APPENDIX D

Supplemental Data Collected on Each Sampling Date During the Monitoring Program

Key to Table Abbreviations:

OCP = Organochlorine Pesticides
OPI = Organophosphorus Insecticides
CPH = Chlorophenoxy Herbicides
VO = Volatile Organics
HM = Heavy Metals
MPN = Most Probable Number of Coliforms per 100 ml
TPC = Standard Total Plate Count per ml

Key to Observations (Last Column):

1 = Low Turbidity, No Unusual Odor or Color
2 = Moderate Turbidity; No Unusual Odor or Color
3 = High Turbidity; No Unusual Odor or Color
4 = Clear, Colorless, No Unusual Odor

Key to Sites:

A = Catharpin, Upper Bull Run Above Treated Sewage Discharges
B = Bull Run Below Treated Sewage Discharges
C = Intake Water at the Fairfax County Water Authority's Water Treatment Facility
D = Finished Water at the Fairfax County Water Authority's Water Treatment Facility
E = Distribution System at the Fairfax County Water Authority's Storage Yard
F = Distribution System in Alexandira, Virginia
G = Distribution System in Dumfries, Virginia

TABLE D-1. PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER SAMPLED AT ALL SITES (A, B, C, D, E, F)
FOR THE ENTIRE SAMPLING PERIOD - JUNE, 1975 - MAY, 1976
(No data indicates testing not performed)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l Total	Chlorine Residual, mg/l Free	Bacteria MPN	Bacteria TPC	Observations
5/21/75	Sunny, Hot 85-90°	A	Adeno Virus Seed Run	7.6 @ 10:40pm	21.0	-	-	-	-	1
			Enteric & Reo Virus Seed Run	8.0 @ 2:00pm 8.2 @ 5:10pm	25.0 26.0	- -	- -	- -	- -	1-2 Surface Scum
5/23/75	Partly Cloudy 80-85°	E	Adeno Virus Seed Run	7.4 @ 9:30am 7.3 @ 12:30pm	20.0 20.0	1.3 1.0	1.0 1.0	- -	- -	4
			Enteric & Reo Virus Seed Run	7.6 @ 2:00pm 7.6 @ 3:50pm	20.0 20.0	1.0 1.0	1.0 1.0	- -	- -	4
5/24/75	-	C	Adenovirus Seed Run	7.4 @ 12:50pm 7.2 @ 2:34 pm	21.0 21.0	- -	- -	- -	- -	1
5/27/75	Sunny 80-85°	D	Adeno Virus Seed Run	7.6 @ 10:10am 7.4 @ 11:45 am	22.0	1.5 1.5	1.5 1.5	- -	- -	4
			Enteric & Reo Virus Seed Run	7.6 @ 12:55pm - @ 2:15pm	22.0 22.5	1.5 1.5	1.5 1.5	- -	- -	4
5/28/75	Sunny 80-85°	F	Adeno Virus Seed Run	7.3 @ 11:10am 7.0 @ 12:25pm	22.0 -	0.6 -	0.5 -	- -	- -	4
			Enteric & Reo Virus Seed Run	7.2 @ 2:15pm 7.2 @ 3:24pm	- -	0.7 0.7	0.7 0.7	- -	- -	4
5/29/75	Partly Sunny 80-85°	C	Enteric & Reo Virus Seed Run	7.2 @ 12:04pm 7.2 @ 1:40pm	21.2 21.2	- -	- -	- -	- -	1
6/2/75	Sunny 80-85°	C	All Pesticides V.O., H.M.	6.9 @ 10:30am	22.6	-	-	-	-	1
		D	All Pesticides V.O., H.M.	7.2 @ 10:50am	22.8	1.3	1.3	-	-	4
		A	Enteric & Reo	7.8 @ 1:35pm	25.2	-	-	Total 1100 (310-2500)	-	1
			Virus Run	7.8 @ 3:24pm	26.1	-	-	Fecal 1100 (310-2500)	-	1
6/3/75	Variable Cloudiness 80-85°	E	All Pesticides V.O., H.M.	7.0 @ 9:10am	21.6	1.0	1.0	-	-	4
		F	All Pesticides V.O., H.M.	7.0 @ 10:33am	22.8	1.3	1.3	-	-	4
			Enteric & Reo Virus Run	6.8 @ 11:25am 6.8 @ 12:40pm	23.0 23.0	- -	- -	Total< 2	0	4

(continued)

TABLE D-1.(continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l		Bacteria		Observations
						Total	Free	MPN	TPC	
6/4/75	Sunny 80-85°	A	All Pesticides V.O., T.M.	7.2 @ 9:05am	19.5	-	-	-	-	1
		B	All Pesticides V.O., T.M.	7.0 @ 11:10am	22.6	0	0	-	-	1-2 "Murky" color
			Enteric & Reo Virus Run	7.0 @ 11:29am 7.2 @ 2:10pm	22.6 23.8	0 0	0 0	Total 7000 (1000-17,000) Fecal 2000	-	1-2 "Murky" color
6/5/75	Party Cloudy 85-90°	E	Enteric & Reo Virus Run	7.0 @ 9:00am 7.2 @ 10:25am	22.4 22.4	1.3 -	1.3 -	T:<2	0	4
6/9/75	Sunny 75-80°	D	OCP V.O.	7.0 @ 9:30am	23.2	2.0	1.5	-	-	4
		C	OCP V.O.	6.9 @ 10:01am	22.6	-	-	-	-	1
		A	Adeno Virus Run	7.0 @ 11:32am 7.1 @ 1:40pm	18.6 20.6	- -	- -	Total 460 (160-1200) Fecal 50 (65-130)	-	1
			Enteric & Reo Virus Run	7.2 @ 2:41pm 7.4 @ 5:10pm	20.6 21.2	- -	- -	Total 330 (110-930) Fecal 110 (20-250)	-	1
6/10/75	Partly Cloudy 70-75°	A	OCP V.O.	7.2 @ 8:55am	18.6	-	-	-	-	1
		B	OCP V.O.	7.0 @ 10:17am	20.6	<0.1	0	-	-	1
			Adeno Virus Run	7.1 @ 10:45am 7.3 @ 12:45pm	21.4 22.2	<0.1 <0.1	0 0	Total 3300 (1100-9300) Fecal 110 (20-250)	-	1
			Enteric & Reo Virus Run	7.2 @ 1:55pm	22.2	<0.1	0	Total 3300 (1100-9300) Fecal 330 (110-930)	-	1
6/11/75	Cloudy 70-75°	F	OCP V.O.	7.0 @ 2:28pm	24.0	1.5	1.1	-	-	4

(continued)

TABLE D -1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l		Bacteria		Observations
						Total	Free	MPN	TPC	
6/11/75	Cloudy 70-75°	E	OCP V.O.	7.2 @ 3:40pm	22.0	2.3	1.8	-	-	4
		C	Adeno Virus Run	7.0 @ 9:15am 7.0 @ 11:00am	22.4 22.4	- -	- -	Total 350 (120-1000) Fecal 7 (1-17)	-	1
			Enteric & Reo Virus Run	7.0 @ 12:03pm 7.2 @ 1:45pm	22.4 22.2	- -	- -	Total 79 (25-190) Fecal 2 (<0.5-7)	-	1
6/12/75	Rain 70-75°	D	Adeno Virus Run	7.4 @ 9:25am 7.4 @ 10:47am	22.6 22.6	2.8 2.6	2.4 2.0	Total <2	0	4
			Enteric & Reo Virus Run	7.4 @ 11:40am 7.4 @ 12:55pm	22.6 22.8	2.7 3.0	2.2 2.7	Total <2	0	4
6/16/75	Partly Sunny 85-90°	C	All Pesticides V.O.	6.45 @ 10:00am	22.6	-	-	-	-	1
		D	All Pesticides V.O.	7.0 @ 10:34am	23.4	2.2	1.8	-	-	4
		F	Adeno Virus Run	6.9 @ 11:30am 7.0 @ 1:05pm	24.2 24.1	2.5 3.1	2.0 2.4	Total <2	0	4
			Enteric & Reo Virus Run	6.9 @ 1:57pm 7.0 @ 3:12pm	24.1 24.1	2.1 1.3	2.1 0.9	Total <2	0	4
6/17/75	Sunny, Hot Humid	A	All Pesticides V.O.	6.9 @ 8:45am	20.6	-	-	-	-	1
		B	All Pesticides V.O.	6.7 @ 1:35pm	25.8	0.3	0.2	-	-	1
		E	Adeno Virus Run	7.2 @ 9:07am 7.2 @ 10:31am	22.7 22.7	1.5 1.4	1.1 1.1	Total <2	0	4
			Enteric & Reo Virus Run	7.2 @ 11:19am 7.4 @ 12:27pm	23.2 23.2	1.2 -	1.0 -	Total <2	0	4
6/18/75	Sunny, Hot Humid	E	*OCP V.O.	7.4 @ 1:40pm	23.8	1.1	1.0	-	-	4
		F	OCP V.O.	7.4 @ 3:03pm	25.4	0.7	0.6	-	-	4

*Began sampling for V.O. inside restroom due to presence of kerosene vapors at outside tap.

(continued)

TABLE D -1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual,mg/l Total	Chlorine Residual,mg/l Free	Bacteria MPN	Bacteria TPC	Observations
6/18/75		B	Adeno Virus Run	7.1 @ 9:13am 7.2 @ 11:40am	24.8 25.9	<0.1 <0.1	<0.1 <0	Total 3300 (1100-9300) Fecal 500 (<50-1300)	-	1
			Enteric & Reo Virus Run	7.2 @ 12:20pm 7.0 @ 2:45pm	26.2 27.1	<0.1 -	0 -	Total 1400 (400-3400) Fecal <200	-	turb.more than in morning run
6/19/75	Sunny, Hot 90-95°,Humid	A	Enteric & Reo Virus Run	7.2 @ 9:20am. 7.2 @ 11:15am	23.2 25.5	- -	- -	Total 1100 (310-2500) Fecal 230 (70-700)	-	1
6/23/75	Sunny, Hot Humid	C	OCP V.O.	7.0 @ 9:05am	23.6	-	-	-	-	1-2,more color than usual
		D	OCP V.O.	7.2 @ 10:15am	24.5	2.5	2.0	-	-	4
		E	OCP V.O.	7.3 @ 2:40pm	25.0	1.7	1.7	-	-	4
		F	OCP V.O.	7.1 @ 3:30pm	26.0	1.4	1.0	-	-	4
		C	Adeno Virus Run	- @ 9:30am 7.0 @ 11:00am	23.6 23.8	- -	- -	Total 8 (1-19) Fecal 5 (<0.5-13)	-	1-2,more color than usual
			Enteric & Reo Virus Run	7.0 @ 11:40am 7.6 @ 1:35pm	23.8 24.0	- -	- -	Total 33 (11-93) Fecal <2	-	1-2, more color than usual
6/24/75	Hazy, Hot Humid	A	OCP V.O.	7.0 @ 8:40am	23.4	-	-	-	-	1
		B	OCP V.O.	7.1 @ 10:00am	25.0	0.2	<0.1	-	-	1
		D	Adeno Virus Run	- @ 10:08am 7.4 @ 11:31am	25.0 24.6	- 1.8	- 1.6	Total <2	0	4
			Enteric & Reo Virus Run	7.4 & 12:30pm 7.2 @ 2:04pm	26.0 27.3	1.8 1.9	1.4 1.8	Total <2	0	4

TABLE D-1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l Total	Chlorine Residual, mg/l Free	Bacteria MPN	Bacteria TPC	Observations
6/25/75	Hazy, Hot 85-90°	E	Adeno Virus Run	7.5 @ 9:16am 7.4 @ 10:34am	25.0 25.0	1.9 1.4	1.7 1.3	Total <2	0	4
			Enteric & Reo Virus Run	7.2 @ 11:16am 7.1 @ 12:30pm	25.0 25.0	1.7 -	1.7 -	Total <2	0	4
6/26/75	Cloudy 75-80° Rain previous evening	F	Adeno Virus Run	7.1 @ 10:14am 7.1 @ 11:26am	26.0 25.9	1.6 2.0	1.5 1.5			filters more color than usual
			Enteric & Peo Virus Run	7.2 @ 12:01pm 6.8 @ 1:25pm	26.0 25.4	2.1 -	1.7 -	Total 2	0	4 filters more color than usual
6/27/75	Cloudy, Showers 75-80°	A	Enteric Virus Run	7.4 @ 9:25am 7.4 @ 11:45am	22.2 24.6	- -	- -	Total 3300 (1100-9300) Fecal 70 (10-170)	-	1-2 more color than usual
		B	Enteric & Reo Virus Run	7.1 @ 2:10pm 7.1 @ 4:20pm	23.6 25.4	0 0	0 0	Total 33,000 (11,000-93,000) Fecal 1100 (200-2500)	-	1-2 more color than usual
6/30/75	Partly Cloudy 80-85° following week-end of heavy rains	B	Adeno Virus Run	7.0 @ 8:58am 6.9 @ 11:05am	22.0 22.4	<0.1 0	0 0	Total 79,000 (25,000-190,000) Fecal 11,000 (3100-25000)	-	3
			Enteric & Reo Virus Run	7.1 @ 11:55am 6.8 @ 2:00pm	22.2 23.4	<0.1 -	0 -	Total 49,000 (17,000-130,000) Fecal 4900 (1700-13000)		3
		C	All Pesticides V.O.	6.8 @ 1:50pm	23.8	-	-	-	-	1-2
		D	All Pesticides V.O.	7.1 @ 2:25pm	24.6	2.0	1.8	-	-	4
		E	OCP V.O.	7.3 @ 3:35pm	24.2	1.5	1.2	-	-	4
		F	OCP V.O.	7.6 @ 4:45pm	26.1	1.1	0.7	-	-	4

TABLE D-1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual,mg/l		Bacteria		Observations
						Total	Free	MPN	TPC	
7/1/75	Sunny 80-85°	B	All Pesticides V.O.	7.0 @ 8:30am	21.6	<0.1	0	-	-	2-3
		A	All Pesticides V.O.	7.2 @ 9:40am	20.9	-	-	-	-	1-2
			Adeno Virus Run	7.3 @ 10:06am 7.4 @ 12:15pm	21.0 22.4	- -	- -	Total 7000 (2300-17000) Fecal 600 (<50-1500)	-	1-2
			Enteric & Reo Virus Run	7.3 @ 1:00pm 7.9 @ 3:00pm	22.4 23.4	- -	- -	Total 1100 (310-2500) Fecal 110 (20-250)	-	1-2
7/3/75	Sunny 90-95°	E	Adeno Virus Run	7.2 @ 9:20am 7.4 @ 10:40am	24.6 29.6	1.2 0.8	1.0 0.6	Total <2	0	4
7/7/75	Cloudy, Showers	C	OCP V.O., H.M.	7.0 @ 9:00am	24.5	-	-	-	-	1-2, slight musty odor
		D	OCP V.O., H.M.	7.6 @ 9:25am	24.8	1.7	1.6	-	-	4
			Enteric Virus Run	7.6 @ 9:40am 7.1 @ 10:55am	24.8 24.9	1.8 -	1.4 -	Total <2	0	4
		F	OCP, V.O., H.M.	7.2 @ 10:50am	27.0	2.2	1.9	-	-	4
		E	OCP, V.O., H.M.	7.1 @ 12:35pm	23.8	1.1	0.8	-	-	4
7/8/75	Partly Cloudy 80-85°	C	Enteric Virus Run	7.3 @ 9:30am 6.7 @ 11:06am	24.5 24.5	- -	- -	Total 130 (35-300) Fecal 13 (3-31)	-	1-2,black suspended matter appeared at end of run
		A	OCP, V.O., H.M.	7.2 @ 2:20pm	24.8	-	-	-	-	1-2
		B	OCP, V.O., H.M.	7.5 @ 3:05pm	25.5	<0.1	0	-	-	1-2
7/9/75	Partly Cloudy 80-85°	B	Enteric Virus Run	7.3 @ 9:15am 7.3 @ 11:05am	24.4 25.8	<0.1 <0.1	0 0	Total 5000 (6500-13000) Fecal 2000 (<500-7000)	-	1-2
7/10/75	Partly Cloudy 80-85° Showers in Evening	A	Enteric Virus Run	7.5 @ 10:03am 7.4 @ 12:45pm	22.8 24.2	- -	- -	Total 4900 (1700-13000) Fecal 500 (<50-1300)	-	1

TABLE D-1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l Total	Chlorine Residual, mg/l Free	Bacteria MPN	Bacteria TPC	Observations
7/11/75	Partly Sunny 80-85°	F	Adeno Virus Run	7.4 @ 10:21am 7.1 @ 11:41am	26.8 26.8	1.2 1.3	0.9 0.7	Total <2	0	4
7/14/75	Rain 75-80° following weekend of heavy rains	A	Enteric Virus Run	7.1 @ 9:08am 7.2 @ 10:50am	21.0 21.0	- -	- -	Total 79,000 - (25,000-190,000) Fecal 1700 (500-4600)		3
		C	All Pesticides V.O.	6.8 @ 1:00pm	24.4	-	-	-	-	2
		D	All Pesticides V.O.	7.1 @ 1:20pm	25.4	1.6	1.5	-	-	4
		F	OCP, V.O.	7.4 @ 2:10pm	26.0	0.8	0.6	-	-	4
		E	OCP, V.O.	7.2 @ 3:27pm	23.8	0.8	0.7	-	-	4
7/15/75	Variable Cloudiness 80-85°	B	Enteric Virus Run	7.1 @ 9:04am 7.2 @ 10:42am	22.0 23.0	<0.1 0	0 0	Total 33,000 - (11,000-93,000) Fecal 3300 (1100-9300)		2
			All Pesticides V.O.	7.1 @ 9:04am	22.0	<0.1	0	-	-	2
		A	All Pesticides V.O.	7.4 @ 10:00am	21.0	-	-	-	-	2
7/21/75	Hot, Sunny 90-95°	C	OCP, V.O.	7.4 @ 9:20am	24.2	-	-	-	-	1
		D	OCP, V.O.	7.4 @ 10:34am	25.0	1.9	1.7	-	-	4
		F	OCP, V.O.	7.5 @ 1:25pm	26.6	0.5	0.5	-	-	4
		E	OCP, V.O.	7.3 @ 3:00pm	24.6	1.0	0.9	-	-	4
		C	Adeno Virus Run	7.4 @ 10:00am 7.0 @ 11:41am	24.2 24.8	- -	- -	Total 23 (7-70) Fecal 8 (1-19)	-	1 at end of Run 3 yellow color "gamey"smell
			Enteric & Reo Virus Run	7.1 @ 12:30pm	24.8	-	-	Total 33 (11-93) Fecal 2 (<0.5-7)	-	1
7/22/75	Sunny, Hot 90-95°	B	OCP, V.O.	7.2 @ 8:25am	23.8	0	0	-	-	2
		A	OCP, V.O.	7.1 @ 9:42am	23.2	-	-	-	-	1-2

TABLE D-1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l Total	Chlorine Residual, mg/l Free	Bacteria MPN	Bacteria TPC	Observations
7/22/75	Sunny, Hot 90-95°	A	Adeno Virus Run	7.4 @ 10:20am 7.2 @ 11:59am	24.6 26.4	– –	– –	Total 17,000 (4300-49,000) Fecal 500 (<50-1300)	–	1-2
			Enteric-Reo Virus Run	7.4 @ 1:00pm 6.9 @ 4:00pm	26.0 26.8	– –	– –	Total 23,000 (7000-70,000) Fecal 800 (100-1900)	–	1
7/23/75	Sunny, Hot 90-95°	D	Adeno Virus Run	7.4 @ 9:55am 7.5 @ 11:10am	25.7 25.9	1.5 1.5	1.5 1.4	Total <2	0	4
			Enteric Virus Run	7.5 @ 12:20pm	26.2	1.4	1.0	Total <2	0	4
7/24/75	Sunny, Hot Humid 85-90°	B	Adeno Virus Run	7.4 @ 9:10am 7.4 @ 11:00am	25.5 25.5	0 0	0 0	Total 3300 (1100-9300) Fecal 500 (<50-1300)	–	1
			Enteric & Reo Virus Run	7.5 @ 12:24pm 7.1 @ 2:10pm	26.7 27.1	0 0	0 0	Total 4900 (1700-13,000) Fecal <200	–	1
7/28/75	Sunny, Hot Humid	B	Enteric Virus Run	7.4 @ 8:39am 7.4 @ 10:25am	23.4 25.6	0 –	0 –	Total 3300 (1100-9300) Fecal 200 (<50-700)	–	1
		C	All Pesticides V.O.	6.6 @ 12:35pm	25.0	–	–	–	–	1 Color less than usual
		D	All Pesticides V.O.	7.2 @ 1:25pm	27.0	1.8	1.8	–	–	4
		F	OCP, V.O.	7.3 @ 2:26pm	28.0	0.8	0.4	–	–	4
		E	OCP, V.O.	7.1 @ 3:30pm	25.5	0.9	0.8	–	–	4
7/29/75	Sunny, Hot 90-95°	A	Enteric Virus Run	7.5 @ 9:15am 7.4 @ 11:10am	23.0 24.0	– –	– –	Total 1700 (500-4600) Fecal 200 (<50-700)	–	1
			All Pesticides V.O.	7.4 @ 8:26am	23.0	–	–	–	–	1
		B	All Pesticides V.O.	7.1 @ 12:35pm	27.0	<0.1	0	–	–	1

TABLE D-1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l Total	Chlorine Residual, mg/l Free	Bacteria MPN	Bacteria TPC	Observations
8/4/75	Sunny, Hot Humid following weekend of same	C	OCP, V.O., H.M.	6.9 @ 9:15am	27.0	-	-	-	-	1-2
			Enteric Virus	7.2 @ 9:35am	27.0	1.5*	1.4*	Total <2	-	1-2
			Run	7.3 @ 11:30am	26.4	-	-			
		D	OCP, V.O., H.M.	7.6 @ 10:20am	27.5	1.9	1.6	-	-	4
		F	OCP, V.O., H.M.	7.2 @ 11:30am	28.5	0.5	0.2	-	-	4
		E	OCP, V.O., H.M.	7.1 @ 12:50pm	27.0	0.7	0.6	-	-	4
8/5/75	Sunny, Hot Humid following evening of thunderstorms	A	OCP, V.O., H.M.	7.5 @ 8:25am	25.5	-	-	-	-	1
			Enteric Virus	7.6 @ 9:06am	25.0	-	-	Total 23,000 (7000-70,000) Fecal 1300 (300-3100)	-	1
			Run	7.3 @ 11:03am	26.5	-	-			
		B	OCD, V.O., H.M.	7.6 @ 12:55pm	28.0	<0.1	0	-	-	1
8/6/75	Cloudy, Chance of Showers 75-80°	B	Enteric Virus	7.5 @ 8:25am	26.0	<0.1	0	Total 7900 (2500-19,000) Fecal 1300 (300-3100)	-	1
			Run	7.5 @ 10:00am	26.0	-	-			
8/7/75	Partly Cloudy 70-75°	D	Enteric Virus	7.6 @ 9:06am	26.0	1.7	1.5	Total <2	0	4
			Run	7.6 @ 10:16am	26.5	1.8	1.7			
8/11/75	Partly Cloudy 80-85°	B	Enteric Virus	7.6 @ 8:39am	29.0	<0.1	0	Total 2300 (700-7000) Fecal 500 (<50-1300)	-	1
			Run	7.5 @ 10:44am	29.0	<0.1	0			
		C	All Pesticides V.O.	7.0 @ 12:50pm	27.0	-	-	-	-	2
		D	All Pesticides V.O.	7.3 @ 1:07pm	27.5	1.7	1.5	-	-	4
		F	OCP, V.O.	7.4 @ 1:54pm	28.5	0.7	0.7	-	-	4
		E	OCP, V.O.	7.4 @ 3:16pm	28.5	0.7	0.5	-	-	4
8/12/75	Partly Sunny Hot 85-90° following evening of heavy thunderstorms	A	All Pesticides V.O.	7.3 @ 9:04am	21.0	-	-	-	-	1-2
			Enteric Virus	7.5 @ 9:50am	22.0	-	-	Total 7900 (2500-19000) Fecal 4900 (1700-13000)	-	1-2
			Run	7.2 @ 11:58am	23.5	-	-			

* Chlorine is present due to cleaning of traveling screen chamber for slime removal.

TABLE D -1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l		Bacteria		Observations
						Total	Free	MPN	TPC	
8/12/75		B	All Pesticides	7.4 @ 2:10pm	26.5	<0.1	0	-	-	1-2 thick surface scum on stream
8/18/75	Sunny 80-85°	D	OCP, V.O.	7.6 @ 8:49am	28.0	2.4	2.2	-	-	4
			Enteric Virus Run	7.6 @ 9:30am 7.1 @ 11:40am	28.0 26.9	1.7 -	1.5 -	Total <2	0	4
		C	OCP, V.O.	7.5 @ 10:10am	27.0	-	-	-	-	2
		F	OCP, V.O.	7.2 @ 11:05	29.0	0.4	0.4	-	-	4
		E	OCP, V.O.	7.2 @ 12:30	27.0	1.0	0.8	-	-	4
8/19/75	Sunny 80-85°	A	OCP, V.O.	7.4 @ 8:50am	23.0	-	-	-	-	1
			Enteric Virus Run	7.5 @ 9:50am 7.4 @ 11:30am	23.5 25.0	- -	- -	Total 7900 (2500-19000) Fecal 200 (<50-700)	-	1
8/20/75	-	B	Enteric Virus Run	7.4 @ 8:50am 7.3 @ 10:35am	25.0 25.0	<0.1 <0.1	0 0	Total 4900 (1700-13000) Fecal 400 (<50-1100)	-	1
8/21/75	-	C	Enteric Virus Run	6.9 @ 8:58am 7.0 @ 10:35am	27.0 27.0	- -	- -	Total 21 (7-63) Fecal 13 (3-31)	-	1-2
8/25/75	Sunny, Hot Humid following evening of heavy thunder-storms	A	Enteric Virus Run	7.7 @ 9:18am 7.3 @ 11:30am	23.0 27.1	- -	- -	Total 140,000 (37000-340,000) Fecal 17,000 (4300-49,000)	-	3
		C	All Pesticides V.O.	7.1 @ 1:35pm	27.5	-	-	-	-	2 - black particles in water
		D	All Pesticides V.O.	7.2 @ 2:05pm	27.8	1.8	1.7	-	-	4
		F	OCP, V.O.	7.4 @ 2:50pm	29.0	0.8	0.7	-	-	4
		E	OCP, V.O.	7.2 @ 3:55pm	27.2	1.4	1.3	-	-	4

TABLE D-1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l		Bacteria		Observations
						Total	Free	MPN	TPC	
8/26/75	Sunny, Hot Humid	B	All Pesticides V.O.	7.2 @ 8:28am	24.8	<0.1	0	-	-	1
			Enteric Virus Run	7.2 @ 9:05am 7.2 @ 10:58am	25.2 26.9	<0.1 <0.1	0 0	Total 4900 (1700-13000) Fecal 700 (100-1700)	-	1
		A	All Pesticides V.O.	7.2 @ 1:35pm	26.4	-	-	-	-	1
8/27/75	Sunny 85-90°	C	Enteric Virus Run	7.1 @ 9:21am 7.0 @ 11:30am	27.5 27.5	- -	- -	Total 33 (11-93) Fecal <2	- -	1-2 1-2
8/28/75	Sunny 80-85°	B	Adeno Seed Run	7.5 @ 8:59am 7.4 @ 10:10am	24.0 24.0	<0.1 <0.1	0 0	-	-	1
			Enteric & Reo Seed Run	7.3 @ 11:05am 7.4 @ 12:10pm	25.0 25.6	<0.1 <0.1	0 0	-	-	1
9/1/75	Rain 70-75° following weekend of heavy rains	C	OCP, V.O.	7.0 @ 9:-5am	25.6	-	-	-	-	2
		D	OCP, V.O.	7.2 @ 10:15am	25.4	2.6	2.1	-	-	4
		E	OCP, V.O.	7.2 @ 11:20am	25.4	1.8	1.8	-	-	4
		F	OCP, V.O.	7.1 @ 1:00pm	27.8	1.5	1.0	-	-	4
9/2/75	Cloudy 80-85°	A	OCP, V.O.	7.4 @ 12:35pm	22.0	-	-	-	-	2
		B	OCP, V.O.	7.2 @ 2:05pm	22.0	-*	-*	-	-	3
9/9/75	Partly Sunny 70-75°	B	All Pesticides V.O., H.M.	7.4 @ 9:00am	22.0	<0.1	0	-	-	1
		A	All Pesticides V.O., H.M.	7.6 @ 10:00am	20.0	-	-	-	-	1
		D	All Pesticidus V.O., H.M.	7.2 @ 11:30am	24.0	2.9	2.7	-	-	4
		C	All Pesticides V.O., H.M.	7.3 @ 12:00N	23.4	-	-	-	-	2-3 more color than usual
		F	OCP, V.O., H.M.	7.2 @ 12:55pm	26.0	2.1	1.9	-	-	4, water very effervescent
		E	OCP, V.O., H.M.	7.2 @ 2:30pm	24.0	1.0	0.5	-	-	4

* Water too turbid to test.

TABLE D-1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l		Bacteria		Observations
						Total	Free	MPN	TPC	
9/10/75	Cloudy 60-65°	B	OCP, V.O., H.M.	7.5 @ 8:00am	19.2	<0.1	0	-	-	1
		A	OCP, V.O., H.M.	7.4 @ 9:10am	15.0	-	-	-	-	1
		C	OCP, V.O., H.M.	6.9 @ 10:18am	22.6	-	-	-	-	1, more color than usual
		D	OCP, V.O., H.M.	7.2 @ 10:35am	23.2	2.1	1.7	-	-	4
		F	OCP, V.O., H.M.	7.2 @ 11:20am	25.4	1.6	1.4	-	-	4
		E	OCP, V.O., H.M.	7.3 @ 1:00pm	24.4	0.5	0.4	-	-	4
9/11/75	Partly Cloudy 75-80° Showers in Evening	A	OCP, V.O., H.M.	6.8 @ 8:40am	18.0	-	-	-	-	-
		B	OCP, V.O., H.M.	6.8 @ 9:20am	20.0	-	-	-	-	-
		C	Bi-hourly sampling 12pm - 12pm See Table							
		D	Bi-hourly sampling 12pm - 12pm See Table							
		E	Bi-hourly sampling 12pm - 12pm See Table							
		D	Bi-hourly sampling 12pm - 12pm See Table							
9/12/75	Cloudy 75-80° Showers	A	OCP, V.O., H.M.	7.3 @ 8:00am	21.0	-	-	-	-	1
		B	OCP, V.O., H.M.	7.1 @ 8:45am	22.0	-	-	-	-	1
		F	OCP, V.O., H.M.	7.6 @ 1:25pm	26.0	1.5	1.0	-	-	4,effervescent
		E	OCP, V.O., H.M.	7.5 @ 2:45pm	24.2	1.1	0.8	-	-	4
		C	OCP, V.O., H.M.	6.9 @ 4:45pm	22.6	-	-	-	-	1-2
		D	OCP, V.O., H.M.	7.2 @ 5:25pm	22.6	2.9	2.3	-	-	4
9/13/75	Sunny, Cool Windy 60-65°	B	OCP, V.O., H.M.	7.3 @ 10:50am	18.0	<0.1	0	-	-	1-2
		A	OCP, V.O., H.M.	7.7 @ 11:35am	15.0	-	-	-	-	1
		C	OCP, V.O., H.M.	7.2 @ 12:45pm	22.2	-	-	-	-	1-2
		D	OCP, V.O., H.M.	7.3 @ 1:00pm	22.4	2.2	1.3	-	-	4
		F	OCP, V.O., H.M.	7.3 @ 1:45pm	25.3	1.8	1.2	-	-	4,effervescent
		E	OCP, V.O., H.M.	7.4 @ 2:53pm	23.7	0.9	0.5	-	-	4
9/14/75	Sunny, Cool 65-70°	B	OCP, V.O., H.M.	7.4 @ 10:55am	17.0	0	0	-	-	1
		A	OCP, V.O., H.M.	7.3 @ 11:50am	14.0	-	-	-	-	1,approaching clear and colorless

TABLE D-1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l Total	Free	Bacteria MPN	TPC	Observations
9/14/75	Sunny, Cool 65-70°	C	OCP, V.O., H.M.	6.9 @ 12:55pm	22.0	-	-	-	-	1
		D	OCP, V.O., H.M.	7.1 @ 1:15pm	21.0	2.2	1.8	-	-	4
		F	OCP, V.O., H.M.	7.2 @ 1:40pm	25.0	1.3	1.0	-	-	4,effervescent
		E	OCP, V.O., H.M.	7.3 @ 3:00pm	24.0	1.5	0.5	-	-	4
9/15/75	Partly Cloudy 65-70°	B	OCP, V.O., H.M.	7.5 @ 9:45am	15.0	0	0	-	-	1,approaching clear and colorless
		A	OCP, V.O., H.M.	7.5 @ 10:30am	12.0	-	-	-	-	1, approaching clear and colorless
		C	OCP, V.O., H.M.	6.7 @ 11:30am	22.0	-	-	-	-	1-2
		D	OCP, V.O., H.M.	7.2 @ 11:50am	22.0	2.9	2.2	-	-	4
		F	OCP, V.O., H.M.	7.0 @ 12:15pm	25.0	3.0	2.5	-	-	4, very effervescent
		E	OCP, V.O., H.M.	7.3 @ 2:00pm	23.0	1.0	0.7	-	-	4
9/16/75	Partly Sunny 75-80°	B	OCP, V.O.	7.5 @ 8:55am	15.5	<0.1	0	-	-	1,approaching clear and colorless
		A	OCP, V.O.	7.3 @ 10:00am	14.0	-	-	-	-	1,approaching clear and colorless
		C	OCP, V.O.	6.8 @ 11:10am	21.5	-	-	-	-	1-2, more color than usual
		D	OCP, V.O.	7.0 @ 11:30am	22.0	2.8	2.2	-	-	4
		F	OCP, V.O.	7.0 @ 12:35pm	24.0	2.0	1.5	-	-	4
		E	OCP, V.O.	7.1 @ 3:10pm	22.5	2.0	1.5	-	-	4
9/22/75	Cloudy 70-75°	C	All Pesticides V.O.	7.1 @ 9:35am	21.5	-	-	-	-	1
		D	All Pesticides V.O.	7.2 @ 10:05am	21.5	3.5	3.0	-	-	4
		F	OCP, V.O.	7.3 @ 12:45pm	24.0	1.8	1.6	-	-	4
		E	OCP, V.O.	7.7 @ 3:20pm	22.0	2.1	1.9	-	-	4

TABLE D-1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l Total	Free	Bacteria MPN	TPC	Observations
9/23/75	Heavy Rains 55-60°	B	All Pesticides V.O.	7.2 @ 12:05pm	16.5	-*	-*	-	-	3
		A	All Pesticides V.O.	7.3 @ 1:17pm	16.5	-	-	-	-	3
9/29/75	Sunny 70-75°	E	OCP, V.O.	7.3 @ 11:10pp	20.0	3.0	2.5	-	-	4
		F	OCP, V.O.	7.5 @ 1:50pm	21.5	2.0	1.6	-	-	4
		C	OCP, V.O.	7.0 @ 3:05pm	18.0	-	-	-	-	3
		D	OCP, V.O.	7.0 @ 3:45pm	19.0	2.2	1.7	-	-	4
9/30/75	Sunny 70-75°	A	OCP, V.O.	7.5 @ 8:30am	13.5	-	-	-	-	1
		B	OCP, V.O.	7.4 @ 9:20am	15.0	-	-	-	-	1-2
10/6/75	Sunny 70-75°	E	OCP, V.O., H.M.	7.8 @ 10:15am	19.0	1.4	1.2	-	-	4
		F	OCP, V.O., H.M.	7.6 @ 12:00N	22.5	2.3	1.7	-	-	4
		C	All Pesticides V.O., H.M.	6.7 @ 1:00pm	18.5	-	-	-	-	1
		D	All Pesticides V.O., H.M.	7.1 @ 1:38pm	19.5	2.3	2.1	-	-	4
10/7/75	Partly Sunny 70-75°	A	All Pesticides V.O., H.M.	7.6 @ 8:25am	13.0	-	-	-	-	1,approaching clear and colorless
		B	All Pesticides V.O., H.M.	7.4 @ 11:45am	15.0	<0.1	0	-	-	1
10/8/75	Partly Sunny 70-75°	E	V.O., H.M.	7.6 @ 10:06am	18.5	1.4	1.1	-	-	4
		F	V.O., H.M.	7.4 @ 1:20pm	21.0	1.6	1.3	-	-	4
11/10/75	Partly Sunny in afternoon, Showers in morning	E	OCP, V.O., H.M.	7.1 @ 9:55am	17.5	3.1	2.6	-	-	4
		F	OCP, V.O., H.M.	7.1 @ 1:20pm	19.0	2.5	2.2	-	-	4
		C	All Pesticides V.O., H.M.	6.9 @ 2:25pm	16.0	-	-	-	-	1
		D	All Pesticides V.O., H.M.	7.1 @ 2:50pm	16.5	2.9	2.5	-	-	4
11/11/75		B	All Pesticides V.O., H.M.	7.5 @ 2:35pm	15.5	0	0	-	-	1

* Water too turbid to test.

TABLE D-1 (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l Total	Free	Bacteria MPN	TPC	Observations
11/11/75		A	All Pesticides V.O., H.M.	8.1 @ 3:45pm	14.0	-	-	-	-	1,approaching clear and colorless
12/8/75	Cold 30-35° Snow/Rain	E	OCP, V.O., H.M.	7.0 @ 9:30am	9.5	2.3	2.3	-	-	4
		F	OCP, V.O., H.M.	6.8 @ 10:40am	11.0	2.1	1.6	-	-	4,effervescent
		C	OCP, V.O., H.M.	6.2 @ 2:00pm	8.0	-	-	-	-	1
		D	OCP, V.O., H.M.	6.9 @ 2:40pm	9.0	2.6	2.1	-	-	4
12/9/75		B	OCP, V.O., H.M.	6.6 @ 12:45pm	4.0	-*	-*	-	-	2
		A	OCP, V.O., H.M.	6.9 @ 1:35pm	4.0	-	-	-	-	1
1/12/76	Sunny, Cold 30-35°	E	OCP, V.O., H.M.	7.6 @ 10:08am	4.5	2.1	2.0	-	-	4,In V.O. sampling area slight odor of moth balls
		F	OCP, V.O., H.M.	7.7 @ 11:18am	6.0	2.5	2.2	-	-	4, very effervescent
		C	OCP, V.O., H.M.	7.2 @ 2:45pm	3.0	-	-	-	-	1,2,Caulking matl odor in carbon bldg due to construction
		D	OCP, V.O., H.M.	7.6 @ 3:23pm	4.0	2.9	2.9	-	-	4
1/13/76	Partly Cloudy 40-45°	B	OCP, V.O., H.M.	7.7 @ 12:20pm	2.0	<0.1	0	-	-	1
		**A	OCP, V.O., H.M.	7.3 @ 1:50pm	2.0	-	-	-	-	1,approaching clear and colorless
1/27/76	Heavy Rain 50-55°	A	H.M.	6.3 @ 10:40am	2.5	-	-	-	-	3
2/17/76	Partly Sunny 75-80°	E	OCP, V.O., H.M.	7.5 @ 10:45am	9.0	2.1	1.4	-	-	4,In V.O. sampling area mothball odor
		F	OCP, V.O., H.M.	6.9 @ 1;40pm	11.0	2.1	1.3	-	-	4

* Water too turbid to test.

** Sampling repeated 1/27/76 due to contamination on 1/13/76.

TABLE D-1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l Total	Chlorine Residual, mg/l Free	Bacteria MPN	Bacteria TPC	Observations
2/17/76	Partly Sunny 75-80°	*C	OCP, V.O., H.M.	6.8 @ 2:40pm	6.0	-	-	-	-	3
		D	OCP, V.O., H.M.	7.3 @ 3:05pm	9.5	2.2	1.9	-	-	4
2/18/76	Partly Cloudy 70-75° Windy	B	OCP, V.O., H.M.	7.6 @ 10:10am	11.0	<0.1	0	-	-	1-2
		A	OCP, V.O., H.M.	7.7 @ 11:45am	11.0	-	-	-	-	1
3/8/76	Cloudy Cool 50°	E	OCP, V.O., H.M.	7.6 @ 10:20am	10.5	2.0	1.7	-	-	4, In V.O. sampling area slight odor of moth balls
		F	OCP, V.O., H.M.	7.2 @ 12:35pm	11.0	1.9	1.5	-	-	4
		C	OCP, V.O., H.M.	6.9 @ 3:20pm	9.5	-	-	-	-	1
		D	OCP, V.O., H.M.	7.7 @ 3:55pm	10.5	2.0	1.8	-	-	4
3/9/76	Cold, Snow	B	OCP, V.O., H.M.	7.7 @ 11:10pm	6.0	<0.1	<0.1	-	-	1
		A	OCP, V.O., H.M.	7.8 @ 12:00N	3.0	-	-	-	-	1
4/12/76	Sunny, Cool 45-50°	E	OCP, V.O., H.M.	7.5 @ 10:50am	11.0	1.5	0.7	-	-	4
		F	OCP, V.O., H.M.	8.0 @ 1:45pm	13.0	1.2	0.7	-	-	4
		C	OCP, V.O., H.M.	7.6 @ 2:45pm	11.0	-	-	-	-	2-3
		D	OCP, V.O., H.M.	7.2 @ 3:20pm	15.5	1.3	1.0	-	-	4
4/13/76	Sunny 60-65°	A	OCP, V.O., H.M.	8.3 @ 3:00pm	13.5	-	-	-	-	1,approaching clear and colorless
		B	OCP, V.O., H.M.	7.6 @ 2:00pm	11.0	0	0	-	-	1,approaching clear and colorless
5/10/76	Sunny, Warm 75-80° Very Dry Period	E	OCP, V.O., H.M.	7.4 @ 11:00am	19.5	1.8	1.1	-	-	4
		F	OCP, V.O., H.M.	7.5 @ 2:10pm	19.5	1.9	1.7	-	-	4
		C	OCP, V.O., H.M.	7.1 @ 3:05pm	17.5	-	-	-	-	1
		D	OCP, V.O., H.M.	7.4 @ 3:30pm	18.5	2.6	2.4	-	-	4

* Traveling screen chamber out of service for screen installation.

TABLE D-1. (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH and Time	Temperature °C	Chlorine Residual, mg/l Total	Chlorine Residual, mg/l Free	Bacteria MPN	Bacteria TPC	Observations
5/11/76	Cloudy 65-70°	B	OCP, V.O., H.M.	7.3 @ 8:30am	17.0	0	0	-	-	1, approaching clear and colorless
		A	OCP, V.O., H.M.	7.4 @ 9:20am	15.5	-	-	-	-	1, approaching clear and colorless

TABLE D-2. PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER SAMPLED FOR VOLATILE ORGANICS (VO)[a] AND TOTAL ORGANIC CARBON (TOC) AT ALL SITES (C, D, E, F, G) FOR THE PERIOD JUNE, 1976 - MAY, 1977
(No data indicates testing not performed)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH	Time	Temperature °C	Chlorine Residual, mg/l		Observation[b]
							Total	Free	
6/24/76	Sunny, Hot 80-85°F	C	VO VO(Q) TOC	6.9	11:30am	23.5	-	-	1
		D	VO VO(Q) TOC	7.3	12:55pm	24.5	2.3	2.2	4
		E	VO VO(Q) TOC	7.5	2:35pm	23.5	2.5	1.8	4
		F	VO VO(Q) TOC	7.4	3:40pm	25.0	1.7	1.5	4
		G	VO VO(Q) TOC	7.7	5:10pm	27.5	0.6	0.5	4
6/30/76	Partly Sunny, 80-85°F	D	VO(Q) (Thiosulfate) VO(Q) (ferrocyanide)	7.4	12:30pm	25.0	2.7	2.7	4
		C	VO	7.0	2:15pm	24.0	-	-	1
7/20/76[c]	Sunny, 85-90°F	E	VO VO(Q) TOC	7.4	10:20am	25.0	2.4	2.3	4 (deodorizer odor in sample area)

(continued)

TABLE D-2 (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH	Time	Temperature °C	Chlorine Residual, mg/l		Observation[b]
							Total	Free	
7/20/76		F	VO VO(Q) TOC	7.2	1:35pm	27.5	1.4	1.3	4
		C	VO VO(Q) TOC	7.1	2:40pm	26.0	-	-	1
		D	VO VO(Q) TOC	7.4	3:15pm	26.5	2.1	2.1	4
		G[d]	VO VO(Q) TOC	7.6	4:00pm	29.0	0.2	0.1	4
8/9/76	Rain, 75-80°F Following wk-end of heavy rains	D[e]	VO VO(Q) TOC	7.5	8:35am	24.5	3.0	2.6	4
		C	VO TOC	7.0	9:20am	25.0	-	-	1-2 (H_2S & black susp. solids)
		E	VO VO(Q) TOC	7.2	11:50am	25.0	2.0	1.6	4
		F	VO VO(Q) TOC	7.6	1:00pm	27.0	1.7	1.4	4
		G	VO VO(Q) TOC	7.6	2:55pm	27.0	<0.1	0	4 (brownish color)

(continued)

TABLE D-2 (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH	Time	Temperature ^{o}C	Chlorine Residual, mg/l		Observation[b]
							Total	Free	
8/10/76	Sunny, 80-85^{o}F	D	VO VO(Q) TOC	7.1	9:35am	25.5	2.4	2.2	4
		C	VO TOC	7.0	11:10am	25.5	-	-	1 (Black susp. solids)
		E	VO VO(Q) TOC	7.6	12:00pm	25.0	1.2	1.1	4
		F	VO VO(Q) TOC	7.6	1:05pm	27.0	1.6	1.4	4
		G	VO VO(Q) TOC	7.8	3:15pm	25.5	0.6	0.4	4
8/11/76	Sunny, 85-90^{o}F	E	VO VO(Q) TOC	7.4	9:10am	25.5	1.4	1.4	4
		F	VO VO(Q) TOC	7.4	10:55pm	27.0	1.2	0.9	4
		C	VO TOC	7.0	12:30pm	26.0	-	-	1 (Black susp. solids)
		D	VO VO(Q) TOC	7.4	1:10pm	26.5	2.4	2.3	4

(continued)

TABLE D-2 (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH	Time	Temperature ^{o}C	Chlorine Residual, mg/l		Observation[b]
							Total	Free	
8/11/76	Sunny, 85-90^{o}F	G	VO VO(Q) TOC	7.6	2:45pm	26.5	0.7	0.5	4
8/12/76	Sunny, 85-90^{o}F	E	VO VO(Q) TOC	7.8	8:55am	25.0	1.9	1.7	4
		F	VO VO(Q) TOC	7.4	10:00am	27.0	2.1	1.7	4
		G	VO VO(Q) TOC	7.8	12:15pm	27.0	0.6	0.4	4
		C	VO TOC	7.0	1:05pm	26.5	-	-	1
		D	VO VO(Q) TOC	7.3	1:40pm	27.0	2.1	1.9	4
8/13/76	Sunny, Hot Humid, 90^{o}F	C	VO TOC	7.0	9:15am	26.0	-	-	1 (color more than usual)
		D	VO VO(Q) TOC	7.4	10:15am	26.5	3.0	2.9	4
		E	VO VO(Q) TOC	7.4	11:30am	26.0	2.0	1.9	4

(continued)

TABLE D-2 (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH	Time	Temperature °C	Chlorine Residual, mg/l Total	Chlorine Residual, mg/l Free	Observation[b]
8/13/76		F	VO VO(Q) TOC	7.3	12:40pm	27.5	2.0	1.9	4
		G	VO VO(Q) TOC	7.6	2:05pm	29.0	1.5	1.2	4
9/21/76	Cloudy 70–75°F	F	VO VO(Q) TOC	7.4	8:21am	24.5	1.9	1.6	4
		C	VO TOC	7.1	9:21am	22.5	-	-	1
		D	VO VO(Q) TOC	7.2	9:50am	23.0	3.6	3.1	4
		G	VO VO(Q) TOC	7.6	11:10am	25.0	0.6	0.3	4
		E	VO VO(Q) TOC	7.6	2:03pm	23.0	2.5	2.5	4
10/18/76	Sunny, Cool, 50–55°F	E	VO VO(Q) TOC	7.4	9:00am	17.0	2.2	1.8	4
		F	VO VO(Q) TOC	7.2	10:17am	18.5	1.8	1.5	4 (effervescent)

(continued)

TABLE D-2 (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH	Time	Temperature °C	Chlorine Residual, mg/l		Obser-vation[b]
							Total	Free	
10/18/76		C	VO TOC	6.8	11:10am	15.5	-	-	2
		D	VO VO(Q) TOC	7.3	12:10pm	16.0	2.5	2.5	4
		G	VO VO(Q) TOC	7.5	1:15pm	19.0	0.6	0.5	4
11/8/76	Sunny,cold windy, 38-42°F	G	VO VO(Q) TOC	7.8	9:20am	14.5	1.0	0.7	4
		C	VO TOC	7.0	10:10am	10.0	-	-	1-2
		D	VO VO(Q) TOC	7.4	10:40am	11.0	3.5	3.0	4
		F	VO VO(Q) TOC	7.2	11:35am	14.0	3.1	2.6	4
		E	VO VO(Q) TOC	7.3	2:15pm	12.0	2.9	2.4	4
12/8/76	Partly sunny,cold, 30's	D	VO VO(Q) TOC	7.4	12:20pm	6.0	4.2	3.5	4

(continued)

TABLE D-2 (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH	Time	Temperature °C	Chlorine Residual, mg/l Total	Chlorine Residual, mg/l Free	Observation[b]
12/8/76		C	VO TOC	-	3:30pm	5.5	-	-	1
12/13/76	Sunny,Cold Windy,40's°F	E	VO VO(Q) TOC	7.2	3:00pm	7.5	3.2	2.6	4
12/14/76	Sunny,cold 40's°F	F	VO VO(Q) TOC	7.4	3:55pm	8.0	2.1	1.6	4
12/15/76	Cloudy, 40's°F	G	VO VO(Q) TOC	7.8	2:25pm	9.0	1.9	1.6	4
1/11/77	Sunny,cold low 30's°F	G	VO VO(Q) TOC	7.7	9:30am	11.0	0.9	0.5	4
		C	VO TOC	6.8	10:33am	4.0	-	-	1
		D	VO VO(Q) TOC	7.2	11:40am	4.5	2.5	2.4	4
		F	VO VO(Q) TOC	6.9	12:30pm	5.0	2.4	1.9	4
		E	VO VO(Q) TOC	7.1	3:12pm	5.0	2.6	2.2	4

(continued)

TABLE D-2 (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH	Time	Temperature °C	Chlorine Residual, mg/l		Observation[b]
							Total	Free	
2/8/77	Sunny, 30–35°F	G[f]	VO VO(Q) TOC	7.7	9:57am	4.5	< 0.1	0	4
		C	VO TOC	7.1	10:45am	5.0	-	-	1
		D	VO VO(Q) TOC	7.3	11:10am	5.5	2.4	2.1	4
		F	VO VO(Q) TOC	7.2	12:15pm	5.0	2.3	2.0	4
		E	VO VO(Q) TOC	7.4	3:00pm	5.5	2.7	2.3	4
3/7/77	Partly Cloudy, 50–55°F	D[e]	VO VO(Q) TOC	7.6	9:10am	7.0	2.5	1.9	4
		C	VO TOC	7.2	9:55am	5.5	-	-	4
		G	VO VO(Q) TOC	7.3	10:40am	8.0	1.7	1.4	4
		F	VO VO(Q) TOC	7.2	11:45am	9.0	1.9	1.5	4

(continued)

TABLE D-2 (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH	Time	Temperature °C	Chlorine Residual, mg/l		Observation^b
							Total	Free	
3/7/77		E	VO VO(Q) TOC	7.4	2:45pm	7.0	2.5	2.2	4
3/8/77	Sunny, 54-59°F	G	VO VO(Q) TOC	7.4	9:20am	9.0	1.5	1.2	4
		C	VO TOC	7.0	10:00am	6.0	-	-	1
		D	VO VO(Q) TOC	7.2	11:30am	8.0	2.1	2.1	4 (Paint odor in air)
		F	VO VO(Q) TOC	7.0	12:10pm	9.0	1.8	1.8	4
		E	VO VO(Q) TOC	7.4	2:15pm	8.0	2.2	1.9	4
3/9/77	Sunny, 65-70°F	G	VO VO(Q) TOC	7.6	9:20am	9.5	1.5	1.4	4
		C	VO TOC	7.0	9:55am	6.0	-	-	1
		D	VO VO(Q) TOC	7.4	10:50am	8.5	2.3	2.1	4

(continued)

TABLE D-2 (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH	Time	Temperature °C	Chlorine Residual, mg/l		Observation[b]
							Total	Free	
3/9/77		F	VO VO(Q) TOC	7.2	11:45am	9.5	1.8	1.7	4
		E	VO VO(Q) TOC	7.8	1:45pm	8.5	2.0	1.9	4
3/10/77	Partly Cloudy, 73-76°F	G	VO VO(Q) TOC	7.6	9:20am	10.0	1.5	1.1	4
		C	VO TOC	7.1	9:50am	7.0	-	-	1
		D	VO VO(Q) TOC	7.1	10:15am	8.0	2.6	2.4	4
		F	VO VO(Q) TOC	7.3	1:30pm	10.0	1.9	1.7	4
		E	VO VO(Q) TOC	7.4	2:50pm	8.0	2.4	2.4	4
3/11/77	Partly Cloudy, 70-75°F	E	VO VO(Q) TOC	7.6	7:50am	8.0	2.1	1.9	4
		G	VO VO(Q) TOC	7.6	9:35am	11.5	1.6	1.4	4

(continued)

TABLE D-2 (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH	Time	Temperature °C	Chlorine Residual, mg/l		Obser-vation[b]
							Total	Free	
3/11/77		C	VO TOC	7.0	10:25 am	7.0	-	-	1
		D	VO VO(Q) TOC	7.3	11:00am	9.0	2.5	2.3	4
		F	VO VO(Q) TOC	7.3	12:05pm	10.0	1.8	1.6	4
4/12/77	Sunny, 85-92°	F	VO VO(Q) TOC	7.3	8:30am	14.5	1.9	1.5	4
		E	VO VO(Q) TOC	7.3	9:30am	14.5	2.4	2.4	4
		D	VO VO(Q) TOC	7.3	10:30am	16.5	2.4	2.4	4
		C	VO TOC	7.4	12:15pm	13.0	-	-	1
		G	VO VO(Q) TOC	7.9	1:05pm	17.5	1.1	0.8	4
5/10/77	Partly Cloudy, Windy, 55-60°F	F	VO VO(Q) TOC	7.2	9:15am	18.5	0.8	0.7	4

(continued)

TABLE D-2 (continued)

Sampling Date	Weather Conditions	Sampling Site	Analyses Performed	pH	Time	Temperature °C	Chlorine Residual, mg/l		Observation[b]
							Total	Free	
5/10/77		E	VO VO(Q) TOC	7.2	10:10am	17.5	2.1	2.1	4
		D	VO VO(Q) TOC	7.5	11:05am	16.5	2.4	2.3	4
		C	VO TOC	6.9	12:35pm	17.5	-	-	1-2 (More color than usual)
		G	VO TOC	8.0	1:15pm	17.5	0.9	0.8	4

---

[a] VO(Q): Samples dechlorinated with sodium thiosulfate.

[b] Observation Code:
1 = Low Turbidity, No Unusual Odor or Color.
2 = Moderate Turbidity; No Unusual Odor or Color.
3 = High Turbidity; No Unusual Odor or Color.
4 = Clear, Colorless, No Unusual Odor.

[c] Beginning 7/20/76 all VO(Q) samples dechlorinated with potassium ferrocyanide.

[d] Tap changed from kitchen to wall tap.

[e] Beginning date for 5-day study of VO changes with time in stored samples.

[f] Change in tap due to freezing of all other water lines.

APPENDIX E

RESULTS OF THE MULTIPLE REGRESSION ANALYSIS OF RAW WATER CHARACTERISTICS AND TRIHALOMETHANE CONCENTRATIONS

APPENDIX E

RESULTS OF THE MULTIPLE REGRESSION ANALYSIS OF RAW WATER CHARACTERISTICS AND THM CONCENTRATIONS

The multiple regression analysis reduced the number of significant independent values to four or less, giving best-fit relationships of the form:

$$\text{TTHM} = a + bx_1 + bx_2 + cx_3 \ldots \qquad [3]$$

The best-fit relationships developed with variables for which there were from 16 to 19 observations are summarized as follows:

$$\text{TTHM} = -20.13 + 0.007\ \text{DO}_s + 0.129\ \text{Rain} + 0.160\ \text{Stage} + 0.197\ \text{Cl}_2\text{-Appl} \qquad [4]$$

$$\text{TTHM} = -16.63 + .005\ \text{DO}_s + 0.123\ \text{Rain} + 0.136\ \text{Stage} + 0.178\ \text{Cl}_2\text{-Dem} \qquad [5]$$

$$\text{TTHM} = -0.56 + 0.007\ \text{DO}_s + 0.122\ \text{Rain} + 0.182\ \text{Cl}_2\text{-Dem} \qquad [6]$$

Where:

TTHM = total trihalomethanes

DO_s = surface dissolved oxygen concentration, percent saturation

Rain = rainfall, in./mo.

Cl_2-Appl = total chlorine applied during treatment, mg/l

Cl_2-Dem = chlorine demand (total applied - total residual), mg/l

Stage = reservoir stage, ft. (maximum = 120)

Next, the analysis was applied to data for which there were 35 observations for all parameters. The resulting equations were:

$$\text{TTHM} = 1.61 + 0.09\ \text{Rain} - 0.056\ \text{Turb} - 0.020\ \text{Color} - 0.562\ \text{Cl}_2\text{-Appl} + 0.600\ \text{Cl}_2\text{-Dem} \qquad [7]$$

$$\text{TTHM} = 1.46 - 0.057\ \text{Turb} - 0.023\ \text{Color} - 0.537\ \text{Cl}_2\text{-Appl} + 0.621\ \text{Cl}_2\text{-Dem} \quad [8]$$

$$\text{TTHM} = 1.21 + 0.100\ \text{Rain} - 0.450\ \text{Cl}_2\text{-Appl} + 0.582\ \text{Cl}_2\text{-Dem} \quad [9]$$

Where:

Color = standard color units
Turb = turbidity, JTU

When chlorine data were omitted, the correlation coefficients were much lower. A summary of the statistics generated by the analyses represented by equations [4] - [9] is presented in Table E-1.

A comprehensive discussion of the meaning of terms displayed in Table E-1 is beyond the scope of intent for this report, but a few comments will be made to help interpret the significance of the statistical data presented there:

1. R^2: The closer R^2 is to 1.00, the better the variables fit the regression equation.
2. MSE: "Mean square error" (MSE) statistic related to the "Sum of squares error"(SSE) in that it is calculated by dividing SSE by the degrees of freedom (number of observations minus number of parameters in the equation minus 1.0). The lower the MSE, the better the indication is that the regression equation describes the true conditions that explain the TTHM variations.
3. SSE: Is that portion of the total sum of squares of the dependent variables (TTHM concentrations squared, in this analysis) which is not accounted for by the "model" but, instead, is due to random errors in measurements, to random variations in the variables themselves, or to unknown factors which were not included in the model. The lower the SSE, the better the equation describes the true conditions that explain the TTHM variations.
4. Press: The "press statistic" results from an analysis in which the variables are removed one at a time and the ability of the regression equation to "predict" that known variable's

TABLE E-1. STATISTICS ASSOCIATED WITH MULTIPLE REGRESSION ANALYSES OF TRIHALOMETHANES AND WATER-QUALITY DATA

Equation	Observations	R^2	[*]MSE	[†]SSE	[††]Press
[4]	16	0.914	0.084	1.550	3.019
	18	0.910	0.093	-	-
[5]	16	0.910	0.094	1.550	3.045
	18	0.893	0.111	-	-
[6]	16	0.888	0.100	1.846	3.314
	19	0.873	0.123	-	-
[7]	35	0.771	0.219	6.36	10.68
[8]	35	0.738	0.242	7.27	10.21
[9]	35	0.684	0.283	8.77	11.86

[*] Mean Square Error

[†] Sum of Squares Error

[††] Press Statistic. See text for discussion.

value is assessed. The process is repeated until all data have been removed and replaced. The value of the press statistic, if low and similar to the value of the SSE, indicates that the data not only are well-described by the regression equation (if R^2 is high) but also that the equation is a good predictor of TTHM values. In other words, a good "model" has been developed.

A summary interpretation of the multiple regression analyses, as indicated by their statistics in Table E-1 is as follows: Equations [4], [5], and [6] provided reasonably good descriptions of the data, but there simply were too few analyses to adjudge those as "good models." The increase in the number of observations caused the R^2 values to decrease, and the Press Statistics were higher than the SSE terms.

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